Residential Applications of Sustainable Stormwater Techniques

To Alleviate Combined Sewer Overflow

Garfield Heights, Ohio

An Honors Thesis (LA 404)

by

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Abstract

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Can you find the river that first made the city? Look behind the unkempt industry, cross the grassy railroad tracks and you will find the rotting piers and there is the great river, scummy and brown, wastes and sewage bobbing easily up and down with the tide, endlessly renewed.

-Ian McHarg, 1969
<u>Design With Nature</u>

Acknowledgements

Foundation

To my family for their continued love and support. Thank you Grandma and Grandpa, Mom, Dad, Taige, Darragh, Benvy and Kat

Guidance

A special thanks to Carla Corbin who helped me through the process and structure of my project, and to the faculty of Ball State University Landscape Architecture

Inspiration

To the 2009 Graduating Class of Landscape Architecture from Ball State University

RESIDENTIAL APPLICATIONS OF SUSTAINABLE STORMWATER TECHNIQUES

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Jarlath L. Caldwell
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I. ABSTRACT

The issue of water quality is often associated with the city of Cleveland, Ohio, usually for its historical lack of concern. Since the inception of the Clean Water Act, there has been a nationwide reduction in point source pollution that has contaminated our waterways. While that source of pollution has been reduce, urban centers that are serviced by a Combined Sewer System (CSS) still emptying raw sewage into waterways as a result of Combined Sewer Overflow (CSO).

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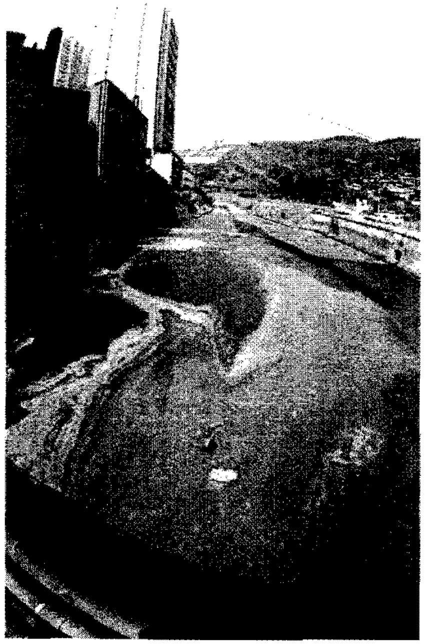

Figure 1.1 Urban Waterway
(www.unon.org)

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III INTRODUCTION

The importance of water can often be overlooked. It flows through our cities and falls from the skies. Yet over the last half decade, it has become apparent the effect we as a society have had on this natural resource. The cause has been both ignorance and self gain at the expense of the environment. In man's quest for wealth, waterways were treated as highways and pollution dumps.

The infrastructure of the past must now be remedied by the coming generation of designers and ecologists. Today's pollution sources are leaked from our cities and our homes through a sewer system that is prone to overflowing. The rain that falls is no longer staying where it lands, but is being carried off into this same system that treats our waste. It is time to reassess the issue and it begins with our homes.

We can no longer plead ignorance after the effects of our actions are known. The city is of human creation, currently in disharmony with the naturally hydraulic world that flows through and beneath it. The steps that need to be taken to return to our natural harmony will begin in our homes and each individuals attempt at solving water pollution.

The city is composed of varying parts and functions with equally varying amounts of impervious surfaces, yet that is something that ties all human development together. The coating of our earth with development causes the same issue wherever it is applied. The urban core is dominated equally by the consolidation of people and the structures and systems that house our efficiency.

Rooftops to roads create an infrastructure of economic development, but also pollution. Beyond this harsh hardscaped landscape and the public mass are the residential neighborhoods built around the family unit and community. Working with these personal elements of humanity, an acceptable sustainable solution has been created to address our water quality dilemma because it is a human goal to strive for the health of our planet and our future.

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V. EFINING THE ISSUE

The course of development in the United States has been dependent upon the waterways along which we build our cities. Yet for all we have gained from our partnership, we have done little to ensure that the quality of water that leaves our cities is as pure as that which enters.

Pollution has become a byproduct of our built environment, and it is therefore in that realm we as designers have the greatest influence.The current dilemma involving the pollution of our waterways can be derived from the basic questions of *what, why, where* and *how*.

- ***What*** is the cause of Combined Sewer Overflow?
- ***Why*** is wastewater exceeding the potential of the System?
- ***Where*** is CSO most pertinent?
- ***How*** is CSO allowed to remain prevalent in our society?

What is the cause of Combined Sewer Overflow?

Combined Sewer Overflow (CSO) is the result of an existing infrastructure found throughout the United States. In total, 772 urban centers have integrated the Combined Sewer System to address human wastewater (USEPA, 2008). The Combined Sewer System (CSS) functions through a subsurface conveyance system that transports wastewater from human developed areas to a wastewater treatment facility. Due to its below ground infrastructure, the system is inelastic and unable to fluctuate with the changing demand on the system. CSO is a defense measure of the CSS designed to deal with an excessive amount of wastewater by dumping raw, untreated sewage into surrounding waterways.

The American urban framework has been expanding and increasing the impervious surface area above the existing CSS's, thereby increasing the demand of the CSS. Expanding the system would require demolition of existing surface development to access the subsurface CSS. Likewise current expansions to CSS's are in themselves below grade installations and therefore inflexible solutions to an inflexible system.

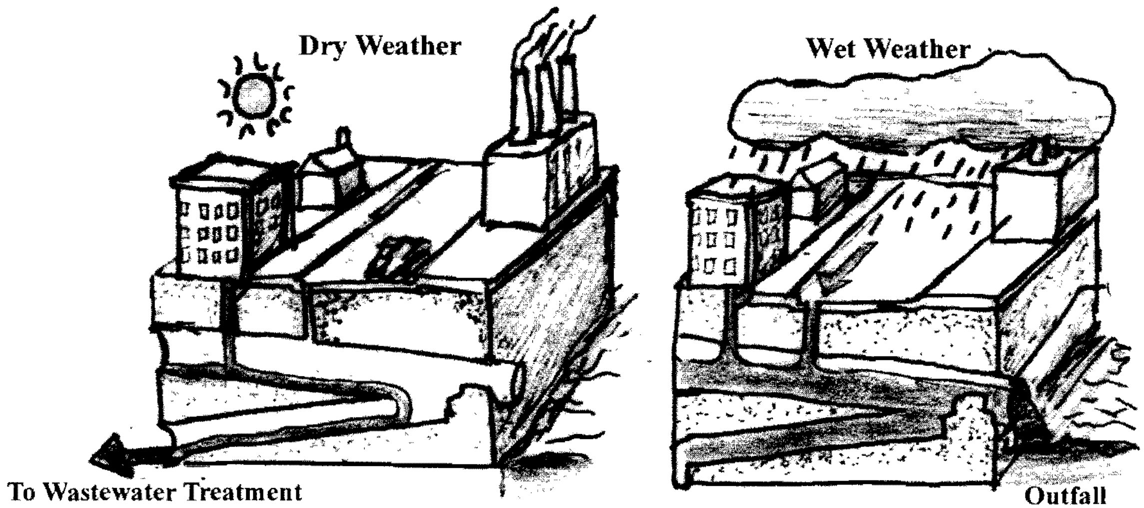

Figure 5.1 CSO Diagram: Wet v. Dry Conditions

Why is wastewater exceeding the potential of the System?

The excessive amounts of urban wastewater can be derived from our social definition of what wastewater is composed of. Currently, wastewater is defined as the collective volume of domestic and commercial sewage, industrial wastewater, and rainwater runoff (USEPA, 2008).

Existing CSS's are capable of treating the demand of wastewater coming from the residential, commercial, and industrial sectors; the issue of CSO arises when the changing demand of rainfall is added to the system. It is from this current definition of wastewater, one which treats all water that has touched human development as equal, that the issue exists when in fact there are varying degrees of waste in our waters.

Rain that falls to the earth and touches our development does not require the same attention to treatment that industrial wastewater or human waste demands.

Where is CSO most pertinent?

The CSS can be found across the United States. Its largest concentrations occur along the East Coast, the Pacific Northwest and the Midwest United States. Extensive attention and projects addressing the issue of stormwater can be found in both the Pacific Northwest and the East Coast in such areas as Portland, Seattle, Philadelphia, Washington D.C. and Maryland (see Chapter XI: Precedent Studies).

However the Midwest has undergone minimal measures in altering CSS's beyond the conventional grey infrastructure expansion. The success of the East and West Coasts lies in the implementation of Green Infrastructure, applications utilizing the natural benefits of evaporation, transpiration, infiltration, and retention, to expand the function of the CSS by focusing on the surface storage and reduced peak flow of stormwater runoff.

The Midwest has been lagging behind in this respect. The waterways that defined the industry and ergo the cities in the Midwest are still under stress of pollution and in need of a solution.

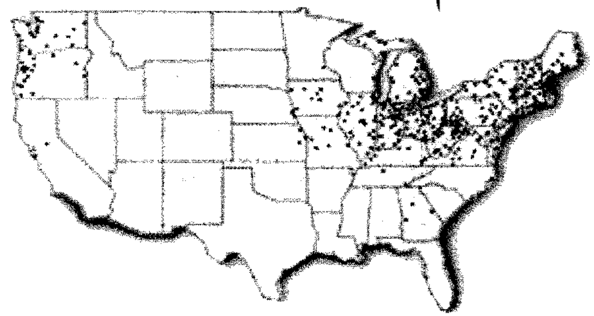

Figure 5.2 CSS Nationwide Locations

How has CSO been allowed to remain prevalent in our infrastructure?

Pollution is not allowed to exist without public acceptance. Pollution is the price our environment pays for growth and advancement. It is often seen as the byproduct of industry, or an outside source beyond the realm of personal connection, however wastewater is the product of each individual person.

The existing system has been successfully kept out of the public realm and therefore public concern of where our water goes once it enters the drain. This water does not emerge again until it is fully treated, or in the event of CSO, when the system is overtaxed. Green Infrastructure integrates people into the process of stormwater treatment within their communities and streets increasing the awareness of water pollution.

Pr ing Needs

CSO has numerous issues that stem from within the system itself, yet there are still more influences that we as people have little ability to alter. These overarching influences have been set in place with the only potential course of action being reaction. Increased rainfall levels coupled with growing impervious surfaces are two elements that provide negligible benefits to stormwater generation and exponential costs to our existing CSS's

Rainfall levels

On September 13th 2008, Chicago, Illinois experienced a 500 year storm, which measured up to nine inches of rainfall over a 24 hour period. As a result, 11 billion gallons of CSO entered Lake Michigan, the source of Chicago's drinking water, and 50 billion gallons of CSO into the Mississippi River. (Camarata, 2009 p. 9). This example showcases the result of the full range in rainfall potential.

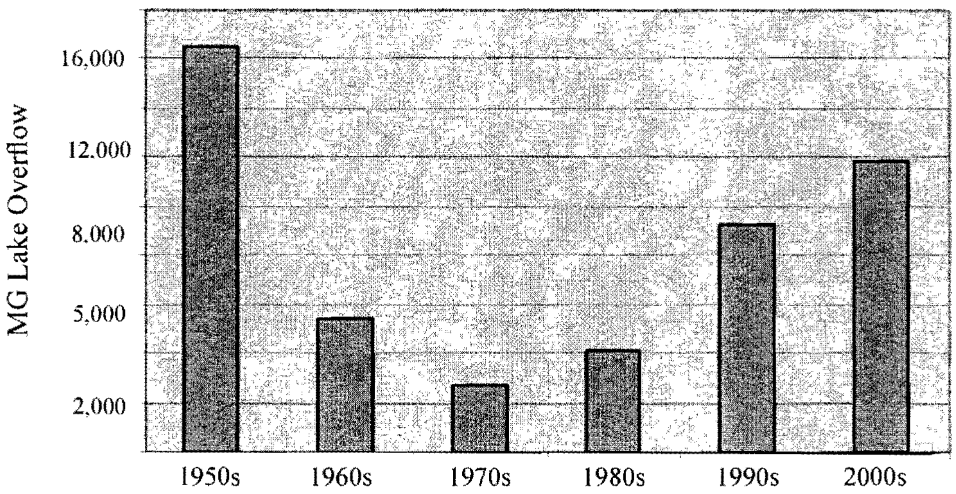

Figure 5.3: Total Chicago CSO by Decade
(Camarata, p. 10)

A 500 year storm is a rare occurrence yet the results of its power have been seen, and the trend over the last century has shown that rain events are growing in intensity. From the first half of the 20th century to the second, there has been a 36% increase in the design rainfall level, meaning municipal stormwater designers have to build systems to account for more waste stormwater (Ibid., p. 12).

To provide a hypothetical example, a designed storm event level of a 2 inch rainfall from the first half of the century would have to be increased to a 2.72 inch designed level by today's standards. In order for the city of Chicago to maintain the same service it has from the first half of the century to todays standards, the city would need to increase the diameter of every sewer pipe by 17% (Ibid., p.12). An alteration of the entire subsurface infrastructure of Chicago is needed just to maintain the required treatment capacity as set by the city standards.

Impervious growth

Along with growing environmental pressures, the human landscape has expanded the demand of existing infrastructure. The course of development measures success based on the expanse of human development. As expansion enters into natural, rural tracts of land, an impervious layer of development is blanketing the earth.

Continuing with Chicago as a case study, between the years of 1982 and 1997, the city's population increased by 12%. During that same time period, the measure of developed land increased by 25% (Ibid., p. 9). For every unit of population gain, twice as many units of development are occurring.

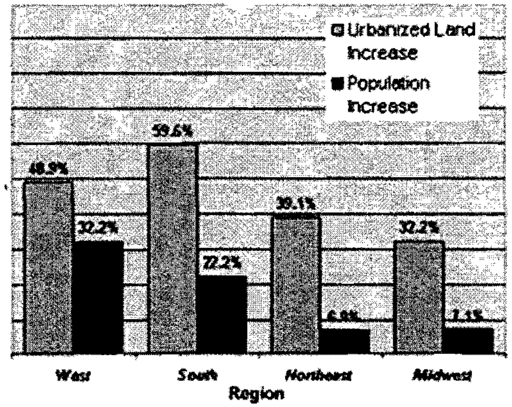

Figure 5.4
Population vs. Urban Land Growth 1982-1997
(Camarata, p.14)

The nationwide trend, Figure 5.2, follows a similar pattern revealing a pressing national crisis as we are not only continuing to expand our existing infrastructure, but through doing so, have reduced the infiltration potential for growing rainfall levels. With the growth Chicago has experienced since 1982, the region has experienced a 10-24 billion gallon loss in infiltration and potential recharge of groundwater tables (Ibid., 9).

The current course of development has created a barrier over the earth's surface that has contributed to rising water pollution events and falling water tables.

By disrupting the natural process of the water cycle, the touch of human influence has entered into a detrimental mentality of water where polluted waterways have become the norm within developed cities.

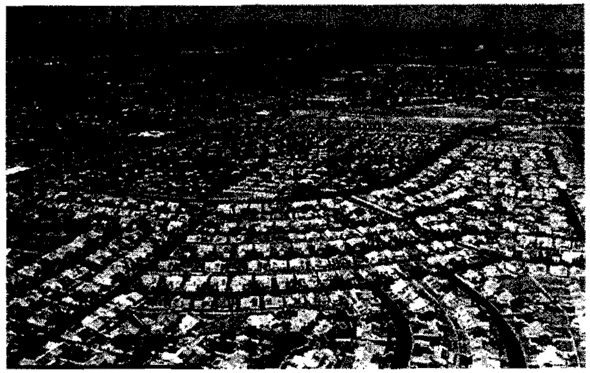

Figure 5.5 Urban Sprawl, Las Vegas NV
(www.nwas.org)

VI THE PHILOSOPHY OF WATER

Water and life exist in a living partnership. The waters that flow through us as human beings is the same that falls on our lands and gets swept away to the oceans. The waterways of our bodies translate to the natural world upon which we have built our civilizations. Life has come to the point where advancement is a product of natural exploitation. In 1969, Ian McHarg analyzed the developed world epitomized by the industrialized American cities, and the course urban development has undertaken since the industrial revolution. The highly philosophical approach of McHarg questions the decisions of how our society has advanced in the past by looking at the current results of those decisions.

"If nature receives attention, then it is only for the purpose of conquest, or even better exploitation. We have but one explicit model of the world and that is built upon economics" (McHarg 1992, p. 25).

As he states, the purpose of our growth has become human oriented rather than natural. He continued to analyze the built world that has been spurred by the economic mind set and assesses the effects upon the natural world.

Among the many exploitations of earth, waterways have borne the burden of carrying the results of our advancement.

"Can you find the river that first made the city? Look behind the unkempt industry, cross the grassy railroad tracks and you will find the rotting piers and there is the great river, scummy and brown, wastes and sewage bobbing easily up and down with the tide, endlessly renewed" (Ibid., p. 21).

We have all seen this image, and if not, it can be pictured through his words. Somehow, against our economist mind set, it does not seem right. This living partnership between water and life has been wronged.

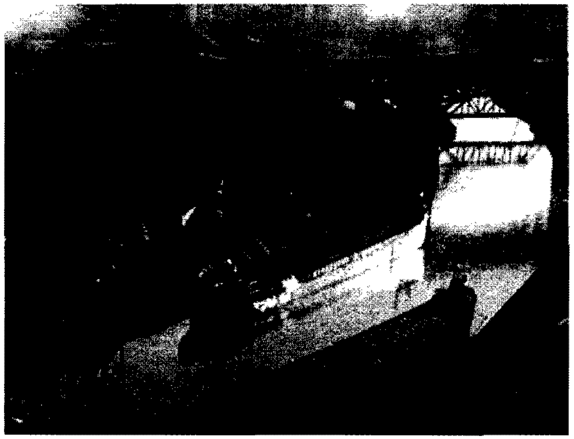

Figure 6.1: Cuyahoga River Industrial Waterfront (www.clevelandmemory.org)

For all that water has given us; our gift to nature is pollution and alteration to natural hydrology. The end result was not achieved over a year nor a decade, but generations. To understand this shift in our view towards the landscape, it becomes important to determine how it came to be. Economic growth is the central driving force for our exploitation of the earth coupled with a removal of the byproducts of production, pollution and waste, partially through our waterways.

Urban waste removal became coupled with water systems to create CSS's. The conventional urban system for water conveyance relied on collection and rapid disposal of stormwater, accomplished through burying or encapsulating many of the existing smaller creeks, and routing the collected stormwater to the major surrounding waterways, wastewater became a waste stream to be disposed of as quickly and efficiently as possible (Leib, Maimone and Neukrug 2008, p. 615).

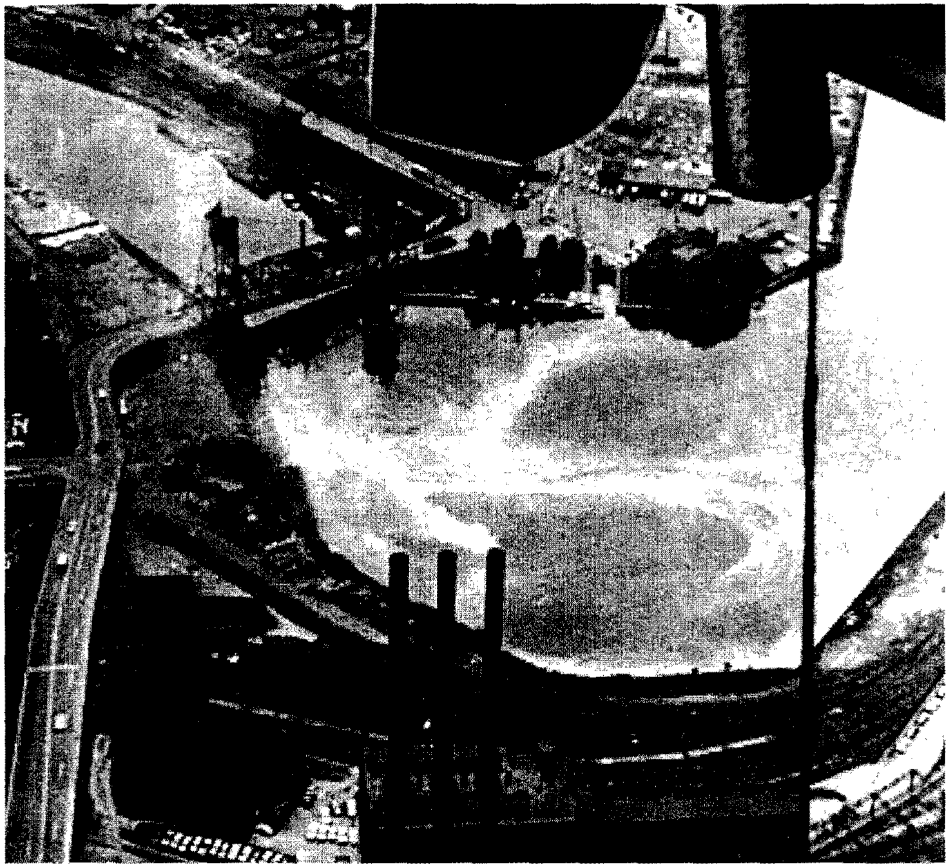

Figure 6.2 Aerial view of the Cuyahoga River as it passes through Cleveland (www.clevelandmemory.org)

Water and waste were seen as similar products to be removed as quickly from the urban setting as possible through existing waterways. The collected runoff carves out existing streams increasing slopes of banks leading to further erosion issues. A loss of infiltration and groundwater recharge in the surrounding watershed combines with a depression in normal water levels in the stream system to lower the regional water table and starve the stream during periods of drought (Farr 2008, p. 175). The increase in peak flows that erode stream banks and at the same time remove water table recharge is a result of the all encompassing definition of "waste" water.

VI ENVISIONED PROJECT GOALS & OBJECTI ES

The integration of Green Infrastructure throughout the urban framework would be the ideal solution to the CSO issue, however acceptance of such a measure would be unexpected until the public became aware of the need for Green Infrastructure.

Therefore, the location of this pilot project shall be in a residential community, worked into the public right of ways and private residences of the people in a demonstration of influence to show the residents that they are part of the issue and therefore, they are part of the solution.

The Design Goals center on the installation of Green Infrastructure and build on the environmental and social benefits of a natural system within a developed region.

Design Goals

I. Incorporate the use of Green Infrastructure to manage stormwater
   - i. Improve water quality and reduce nonpoint source pollution deposition in surrounding waterways
   - ii. Naturalize stormwater management design to alleviate CSO challenge
   - iii. Increase stormwater detention capacity
   - iv. Decrease stormwater discharge to adjacent waterway

II. Enhance the neighborhood livability, connectivity
   - i. Green street emphasis with focus on the pedestrian scale
   - ii. Improve pedestrian circulation through sidewalks and public trail connections
   - iii. Community ownership of the stormwater systems

III. Expand the function of public right of ways
   - i. Beyond service and circulation towards stormwater treatment
   - ii. Stormwater retention
   - iii. Street Tree Initiative

Project Publication Objectives

I. Provide Clarity for Designers & Developers
   - i. Create a design standard document for residential based Best Management Practices utilizing Green Infrastructure to address stormwater management
   - ii. Expand beyond the realm of the subsurface grey system

II. Improve sustainable stormwater management
   - i. Implement Green Infrastructure Best Management Practices to address stormwater
   - ii. Naturalized surface treatment, detention of stormwater

III. Improve Neighborhood identity

IV. Economically feasible integration of Green Infrastructure

VI BENEFITS OF DESIGN

	Ecological	Stormwater Management	Societal
Comprehensive Planning	**Address multiple environmental issues through comprehensive design**	**Applying new management principles to an existing system**	**Incorporating the human community as a part of design**
Green Infrastructure	**Natural Solutions to Human Problems**	**Evaporation, Infiltration, Transpiration, Retention**	**Reduced influence of the grey community on lifestyle**
Green Streets	**Groundwater recharge and canopy elements from trees**	**Linear treatment of stormwater in the public realm**	**Functional vegetated roadways enhance and service the community**
Private Involvement	**Education of the public on the environmental issues of their community**	**Personal accountability for runoff generated from private lots**	**Improve the sense of community through a common goal**

Table 8.1: The Benefits of Design Matrix

When determining the measure of benefit created through design, it is important to identify the benefactors of an improved environment. The scope of design and cliental goes beyond the group covering the monetary cost and encompasses the realm of users, both human and natural.

With conscientious, sustainable design, the ecological and societal systems of the site along with the water cycle, all gain from the components of design. The matrix of growth that results from the integration of design and cliental, creates an improved, holistic community where the gain filters into all components of the site.

IX DEFINITION OF TERMS

Combined Sewer System (CSS) – A wastewater treatment system incorporated in 772 American urban centers that combines all forms of human influenced waters from our built environment into wastewater to be treated at a wastewater treatment facility (EPA).

CSS Wastewater– rainwater runoff, domestic sewage, commercial and industrial wastewater

Combined Sewer Overflow (CSO) – During periods of heavy rainfall or snowmelt the wastewater volume in a CSS can exceed the capacity of the treatment plant, and therefore the excess wastewater into local waterways untreated.

Figure 9.1 Roadway curb bumpout Portland, OR

Grey Infrastructure – The existing subsurface framework of the CSS composed of culverts and storage basins for transportation and detention of wastewater.

Green Infrastructure – A sustainable design system built around the natural processes of evaporation, transpiration, infiltration, and natural retention in the built landscape to address environmental issues.

Point Source Pollution – A single, identifiable source and location of pollution

Nonpoint Source Pollution – A diffuse pollution source brought about by runoff along impervious surfaces collecting natural and human made pollutants.

Outfallshed – The region that contributes wastewater to a treatment facility and the impervious surface area that causes CSO.

Impervious Surface – Human development that does not allow for water infiltration, asphalt, concrete

Public Right of Way – The surface of, and space within, through, on, across, above or below, any public street and any other land dedicated or otherwise designated for a compatible public use, which is owned or controlled by the City.

Runoff- The portion of rainfall, melted snow, or irrigation water that flows across the ground surface and is eventually returned to water resources.

Tree Lawn – The area within the public right of way between the roadway and public sidewalks

X.(REEN INFRASTRUCTURE

Green Infrastructure is a term becoming as common as sustainability, yet the understanding of these terms requires a specific description for the intended function. The key to the design concept of Green Infrastructure is derived from its functionality within the built landscape to reinstitute the natural benefits of evaporation, transpiration, infiltration, and detention that have been lost within the urban setting.

Through the reapplication of natural processes within the built environment, the benefits of Green Infrastructure enhance the function and lifespan of existing grey infrastructure. Along with the mutual enhancement to existing infrastructure, Green Infrastructure has been proven to be an effective tool in reducing stormwater runoff, a cost saving practice in comparison to conventional infrastructure, and instills numerous community benefits beyond stormwater management (Camarata 2009, p. 23).

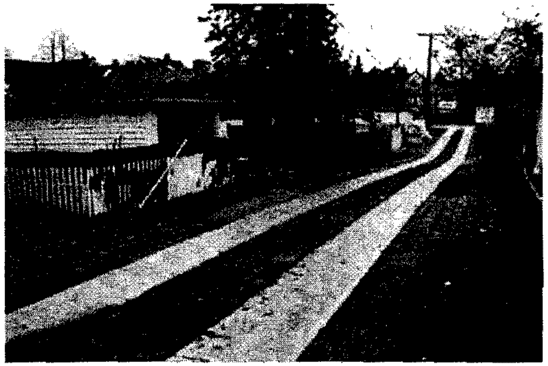

Figure 10.1 Impervious private driveway
(Rooftops to Rivers)

Applications of successful projects shall be addressed in chapter XI. The projects in the following chapter have been installed for the purpose of improving increased CSS demands. The municipalities that piloted these projects understood the hidden cost of human development. When our wetlands and forests are removed, society incurs a cost not accounted for in the economic market.

Our society is entering into a period where the effects of our actions are becoming apparent in daily life as the degraded health of our ecosystems is on the threshold of individual concern.

Green Infrastructure is a balance between the natural, measurable function of a project, and the aesthetic quality that can be integrated within an existing community. The range of project types is diverse and range from private to public installations. Residential land use provides the ideal location to implement Green Infrastructure design due to the quantity and quality it offers.

When looking down on a city, it is apparent that density subsides when moving away from the central urban core and fades into the suburban reaches of human development. A study of the Washington D.C. greater area revealed that 46% of total rooftop areas within the district are of the residential type (Busiek, Molloy, Sullivan, Upchurch and Whitlow 2008, p. 619).

Figure 10.2 Tree lawn rain gardens
(Camarata, p. 4)

Likewise as density drops from almost 100% impervious within the urban core outwards, a patchwork network of underutilized green spaces provide future project locations for Green Infrastructure. The majority of residential land includes green space, which provides the dual benefit of green space, and personal interaction.

CSO water pollution is a nonpoint source pollution with no individual polluter. The CSO outfall is the point source for a societal contamination that can be narrowed down to each individual within that society as contributors to the issue.

The social disconnect can be corrected through the installation of Green Infrastructure by bringing the issue to the residents of a community through community projects and raising their awareness that through these projects, a community can make a difference.

Figure 10.3 Residential Green Street
(Camarata, p. 1)

XI. PRECEDENT STUDIES

Figure 11.1 Reduced impervious surface
(www.seattle.gov)

Figure 11.2 Curb bumpout stormwater inlet
(www.asla.com)

Figure 11.3 Residential rain garden
(www.beltramiswcd.org)

Two regions of the United States have been responsible for the majority of pilot Green Infrastructure projects. The Pacific Northwestern cities of Portland and Seattle, along with the East Coast cities of Philadelphia and Washington D.C. have been at the forefront of Green Infrastructure on the public scale.

Successful installations of Green Infrastructure to date have not been possible without municipal assistance. A large reason for this has been the lack of public understanding. This new principle and its numerous benefits have not been adequately understood by society. On the small scale, installations have been accepted by surrounding communities once the effects are known.

Thanks to the work of the above mentioned cities, Green Infrastructure now has examples that can be referenced as proven projects that have improved the natural and societal quality of communities that have had the benefit of a pilot project. Green Infrastructure is the union of numerous design components; the following projects have successfully integrated these principles into cohesive stormwater treatment systems.

SEA Street Seattle, Washington

Figure 11.4 SEA Street aerial view
(Camarata. p. 24)

SEA Street is a public roadway installation along a previously existing residential right of way. The city of Seattle chose to address the issue of impervious runoff and pollution capture by creating a Natural Drainage System (NDS), which mimics nature by increasing the ability of the local landscape to store and infiltrate runoff. The SEA Street pilot project was completed during the spring of 2001. Bioretention swales, amended soils, plants, and a reduction in impervious roadway were the main components of the design, which perform the functions of improving water quality and quantity while reducing pollution and runoff velocity.

Planted swales situated on both sides of the roadway provide natural conveyance of stormwater over a porous medium not only allowing rainwater to return to the earth, but capturing pollutants from the impervious surface such as oil and grease, heavy metals, pet waste, sediments, chemical fertilizers, and pesticides as well (Seattle Public Utilities, 2009).

The resulting benefits of SEA Street, as shown in Table 11.1, spans the breadth systems present on any site. Through Green Infrastructure, it becomes possible to address the cross boundary benefits of functional design as it relates to Environmental, Social, and Stormwater demands. In the case of SEA Street, measurements made since its completion in 2001 have proven Green Streets are able to retain on site stormwater generation while reducing impervious surfaces.

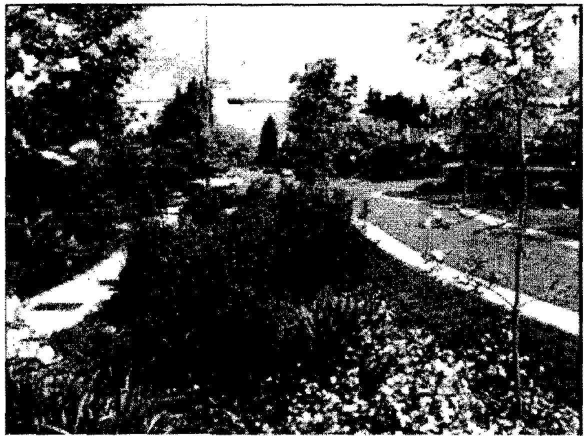

Figure 11.5 Vegetated swale buffer
(www.seattle.gov)

	Environmental	Social	Stormwater
Native Plants	Filter Pollutants	Low maintenance	Increased root zone for water storage
Community Involvement	Human/natural relationship growth	Personal maintenance of street edges	--
Hardscape Reduction	Increased porous surface area	Pedestrian friendly Reduced traffic speed	**Impervious surface reduced by 11%**
Stormwater Reduction	Increased infiltration to water table	Decreased flooding potential	**98-100% retention of rainfall on site**

Table 11.1: SEA Street Design Benefit Table

An additional benefit of Green Infrastructure has been found as the functional capabilities of the practice have begun to enhance the surrounding communities. People are recognizing the aesthetic quality Green Streets are lending to a community adding natural substance to public right of ways along which residential housing units are increasing in value.

A study across the Seattle municipal area, including SEA Street, has revealed that homes along Green Infrastructure projects have increased property values by 3.5-5% more than surrounding homes in the same zip code (MacMullan 2008, p. 3).

Residents are willing to pay more to live along Green Streets, which in the future may be a potential design development to try and revitalize communities through the street systems.

Figure 11.6 Reduced drive lane widths
(www.seattle.gov)

Si: ·ou Street *Portland, Oregon*

The Pacific Northwest provides numerous Green Infrastructure examples to research. Siskiyou Street is an example of a project retrofit of an existing right of way to address the demand on the existing infrastructure.

The 80 year old residential roadway received an alteration in 2006 from designer Kevin Perry. The design consisted of installing two curb extensions into the parking zone along both sides of the roadway. Curb extensions have been used by the City of Portland traditionally to provide improved pedestrian safety. Perry improved the function of these extensions by creating shallow depressions above the existing storm drains allowing stormwater to enter and infiltrate into the ground.

The project totaled $15,000 and two weeks of installation with the benefit of these two 7’ by 50’ bumpouts collecting 10,000 sq ft of runoff from the roadway (ASLA, 2008).

Through this simplistic and cost effective design, runoff that would have originally entered the CSS directly has now been given the opportunity to be retained for plant use and infiltration potential into the groundwater strata. Siskiyou provides an ideal example of a small scale, retrofit application on an existing roadway that creates a reactive water treatment system that can fluctuate its storage potential with the level of runoff that enters into it.

Along with the stormwater success, and similar to the success of SEA Street, the livability along Siskiyou Street has improved, which can be measured by increased property value, and has led to similar project demands throughout the Portland area.

Figure 11.7 Siskiyou St. retrofitted curb bumpouts (www.asla.com)

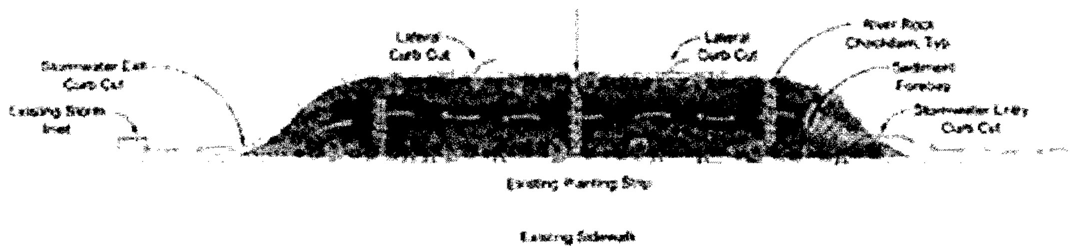

Figure 11.8 Curb bumpout detail plan (www.asla.com)

Along with individual Green Infrastructure examples, municipalities have already begun to assemble extensive research projects compiling persuasive research on the benefit of Green Infrastructure. Washington D.C. has performed multiple studies of its urban setting.

The cities first study, completed in 2007, included tree canopy extension and green roof conversions at a "moderate" scale (any unutilized hardscaped plot or structurally available roof) resulted in a 5-10% decrease in stormwater runoff (Busiek, Molloy, Sullivan, Upchurch and Whitlow 2008, p. 614). The success of the first model set the groundwork for their second model to analyze additional green infrastructure practices. An important component of the model is the equation found at the bottom of the page (Ibid., p. 617).

This rather simple equation helps represent the various functions of sustainable practices in the landscape. A combination of vegetative material, infiltration basins, and temporary storage areas all contribute to the alleviation of excessive runoff.

An important function of the Green Build Out Model beyond the sustainable practices is the breakdown of the urban structures that contribute to runoff. It was found that buildings less than 2,000 sq ft represent approximately 120 million sq ft (46%) of the roughly 260 million sq ft of roof tops in the District (Ibid., p. 619). Buildings of such size are stated as residential or small commercial, which assuming the majority of American cities follow this framework provides a large portion of cities to be influenced by sustainable residential practices.

The Washington D.C. model likewise analyzed street and sidewalk retention practices in their urban setting. They determined that curb bumpout bioretention and sidewalk bioretention planters can service an area ten times their size. For example, one 200 sq ft curb bump out sited in the existing parking lanes of a minor residential street can service a 2,000 sq ft drainage area (Ibid., p. 620). Roadways are the branches that begin to collect runoff from communities. If able to disconnect these branches, the area serviced by a CSS would be diminished.

Figure 11.9 Green Streets in a residential community *(Camarata, p. 42)*

Runoff = Precipitation – potential evapotranspiration – infiltration – storage

Philadelphia has likewise undergone an analysis of its urban network beginning with a breakdown of their city and its impervious surfaces. Soon after the Environmental Protection Agency issued its CSO Control Policy in 1995, Philadelphia began its comprehensive evaluation of its urban framework.

Buildings, parking lots, and roadways were found to compose 80% of their city and are a major source of non point source pollution (Leib, Maimone and Neukrug 2008, p. 615). A design goal the Philadelphia Water Department (PWD) is aiming to retain the first inch of rainfall. This first flush can carry as much as 85% of the pollutants from the impervious surfaces into the system.

The PWD through analyzing the multiple inflows into their CSS (integrated water, wastewater, and stormwater, domestic, commercial, and industrial wastewaters) have come to understand that the one source they as a municipal department have the most impact on is stormwater runoff. It was the final determination of the PWD that CSO can be reduced by 90% if all impervious surfaces are retrofitted over a 20-30 year period.

Without infringing on the freedoms of its citizens, the shared public, and federally maintained urban spaces provide the most opportune resource to begin a citywide change in the philosophy of stormwater. The roadways that meander through residential zones are of significant importance. This interaction between the public roads and private lots presents an issue of how can the two work together to solve the universal problem of runoff.

What it will take to influence residential owners to become part of the solution towards runoff relief may lie in the use of roadways. By utilizing the roadways as public displays of CSO relief projects, they shall inform the public of the personal influence they have on the quality of their water.

Figure 11.10 Green Roof potential Philadelphia PA (Camarata, p. 44)

Cleveland, Ohi

CSO is an issue shared by over 772 cities nationwide affecting 40 million people, mainly focused in the eastern and northwest United States (USEPA, 2008). Since the inception of the Clean Water Act, many of these cities have been addressing water quality issues. On the broad scale, point source pollution has been largely reduced. The issue of nonpoint source pollution has become the new focus of municipalities.

Various regions of the United States have made extensive advancements in addressing nonpoint source pollution with the implementation of Green Infrastructure practices, yet there has been a Midwest neglect when it comes to alternative thinking for current issues of stormwater management.

When analyzing the scope of a project, it is important to recognize the overarching realm of influences on a specific site. Analysis of the regional factors of the site, historical context of what has occurred, and nature of the local watershed are all vital components of a specific site. We shall begin with the Midwest and the major urban center in our study.

Figure 12.1 The industrialized Cuyahoga River (www.clevelandmemory.org)

Cleveland, Ohio, like so many other Midwest centers, is a city that has been born and nourished by the human economic philosophy while having a CSS to remove all evidence to the contrary of human development. Cleveland's proximity along the Cuyahoga River and Lake Erie connected the Midwest City to the waterways of the east. Industry became the city's life blood fueled by the natural resources of the land and fed by its surrounding waterways transporting all of its products including pollution.

It is worth noting that the Cuyahoga River has caught fire more than once in its history documenting the polluted quality of the river, but the blaze of 1969 became the epitome of irresponsible environmental management. At the cost of prosperity, residents of Cleveland saw the backbone of their city burn, and Lake Erie degrade into a lifeless water body along the developed shoreline.

Figure 12.2 1969 Cuyahoga River burning (www.clevelandmemory.org)

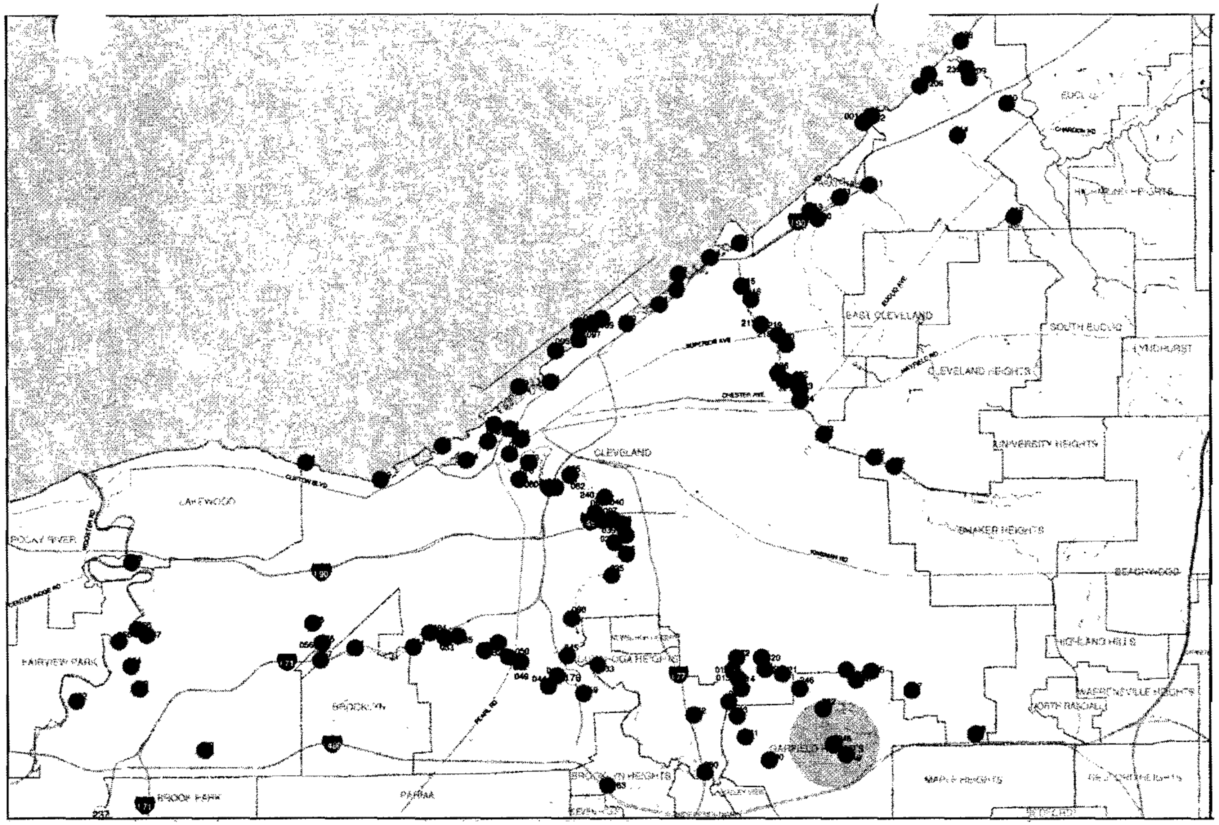

Figure 12.3 NEORSD Greater Cleveland treatment region and CSO outfall locations (www.neorsd.com)

The Cuyahoga River burning was a momentum shifter in the development of the Clean Water Act of 1972 and spearheaded a movement of removing point source pollutants from the Cleveland region, however today the city is still suffering from nonpoint source pollution (Beach and MacDonald 2008, p. 62). While the direct inlet pipes of industrial waste were easily located, the issue with non point source pollution is that no "owner" can be identified. The majority of toxins and pollutants still reaching our waterways are the result of runoff from agricultural land and impervious surfaces. These pollutants are entering the CSS and, since they are a result of a storm event, overflowing into rivers and streams. The Northeast Ohio Regional Sewer District (NEORSD) currently has 126 permitted outfalls where overflows may discharge. Of these 126 outfalls, it has been mapped that a maximum of 82 CSO events occur annually (NEORSD, 2008).

Therefore on average, an overflow event is occurring every 4.45 days in the Cleveland area in more than one location. These present day predictions, even after $900 million invested in projects of the conventional system, warrants further investigation into the alleviation of wastewater reaching the Cleveland CSS (Beach and MacDonald 2008, p. 64).

The Mill Creek Project is an example of a CSO aversion attempt to increase the subsurface storage potential of the CSS. These subsurface projects, known as interceptors, consist of large tunnel systems where the only function is to house excessive stormwater during peak flow. Expansion of the existing grey infrastructure, which in the case of the Mill Creek Project cost over $85 million to complete, continues to hide the issue of CSO below grade and out of the public view.

The concept of Green Infrastructure has yet to be integrated into Cleveland's design principles.

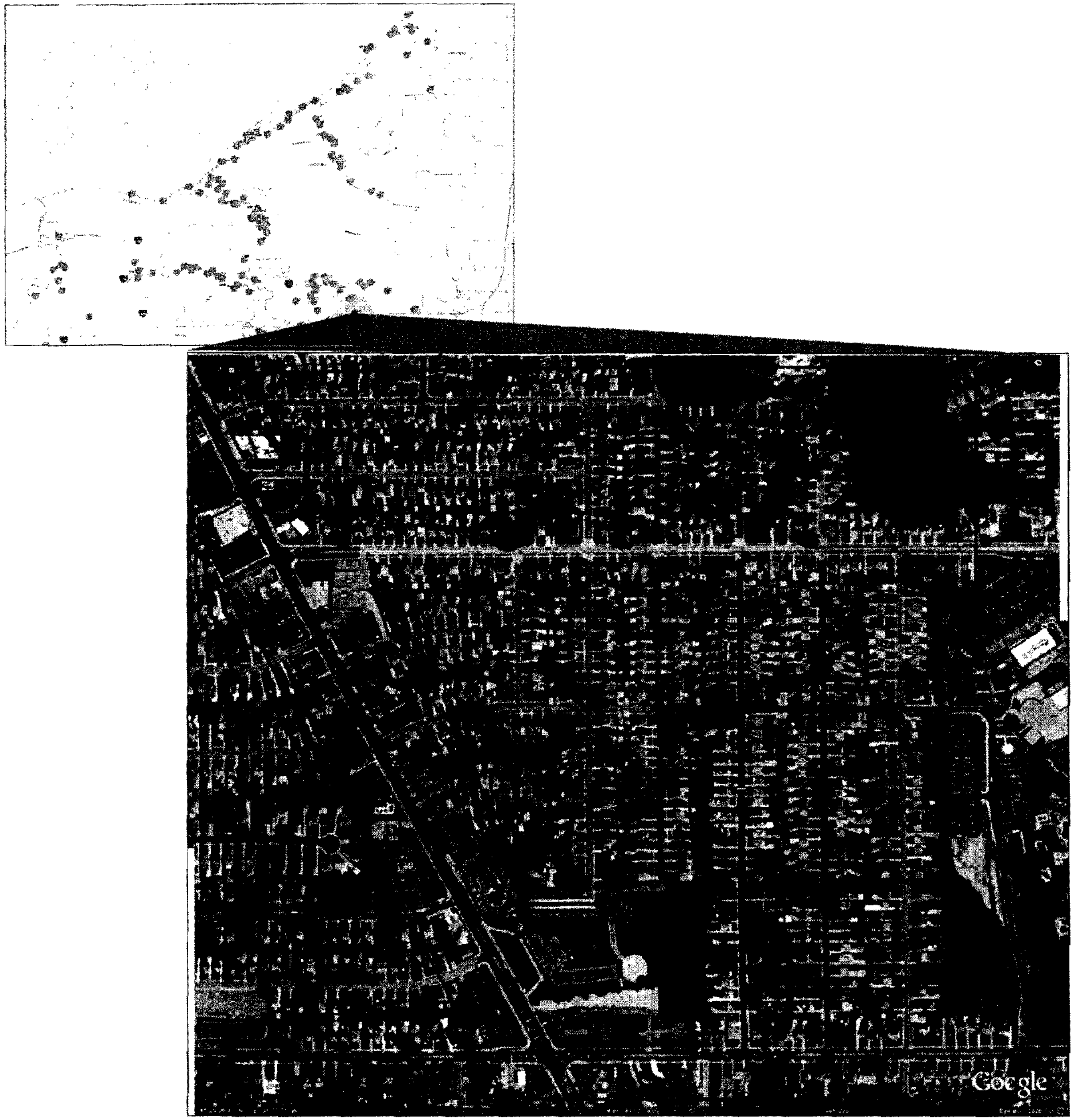

Figure 12.4 Garfield Heights Residential Site Location

Site Selection Criteria

Of the 126 CSO outfall locations to work with, the selection of a specific site was based on the following parameters:

- CSO must overflow more than 50 times annually (roughly once a week)
- CSO location must be outside of the Cleveland city limit
- Location must be adjacent to a residential community that is connected to the Combined Sewer System

CSO frequency was based from the NEORSD CSO Frequency Chart, (Appendix A) which identified the location and number of annual CSO events in the NEORSD. With these requirements, two CSO locations out of the 126 total were potential sites. Upon further research and site visitations, CSO 245 and Garfield Heights was selected as the project location.

Ga ld Heights

Garfield Heights is situated on the southern border of the Cleveland city limits. The location of a site outside of the urban core ensures an integrated mix of both hard and softscapes.

When looking at the makeup of a city, the density goes from high to low from the center out. Likewise the amount of area increases and the density of people decreases as you enter suburbia. It is within this suburban realm that the highest impact can be implemented on sustainable stormwater design. This expanding region has no boundaries as development continues to push into rural land; and as development increases, impervious surfaces grow increasing the demand on existing CSS's.

Garfield Heights falls in the Southerly Treatment Facility of Cleveland. The Greater Cleveland Metropolitan Area is divided into 3 treatment regions with the southerly region comprising the largest land area covering 225 square miles and 41 municipal districts with a population of 601,000 people (NEORSD, 2008). The extent of the treatment facility boundary is a result of Cleveland's sprawl. The waste water treatment center is now one of the largest in the country in order to address this increased demand from impervious infrastructure. (Southerly Treatment Facility, Appendix A).

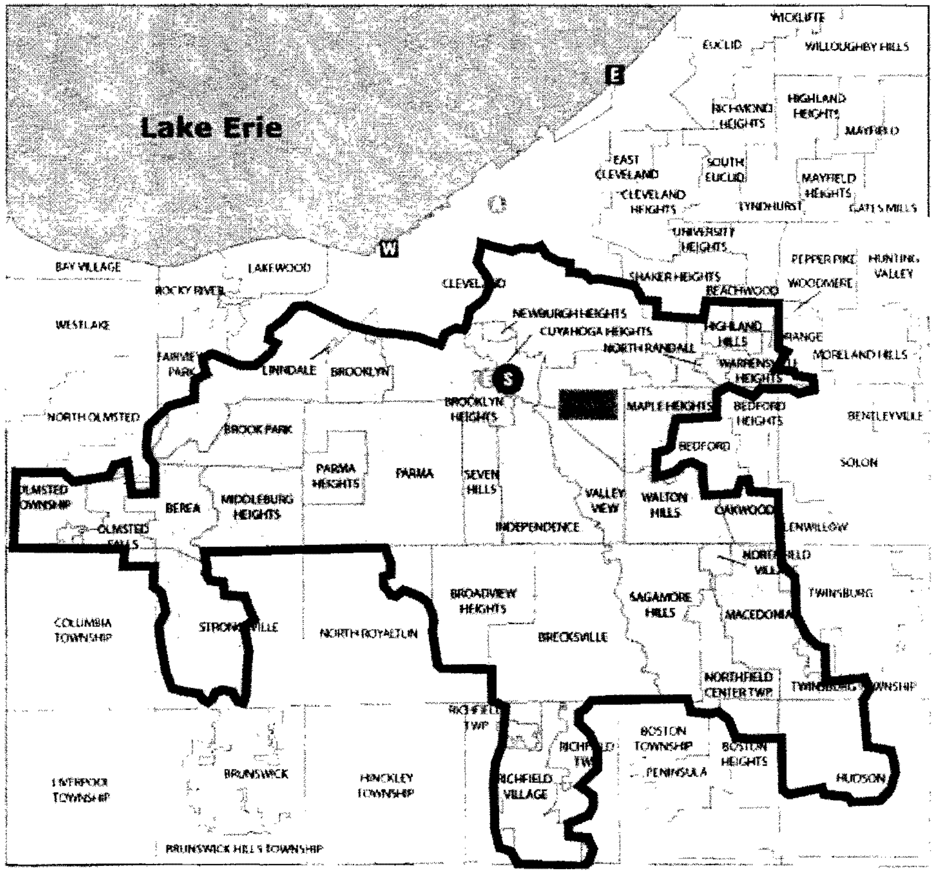

Figure 12.5 NEORSD Southerly Treatment Facility treatment area
(www.neorsd.com)

Mi reek Watershed

Along with the human wastewater shed, Garfield Heights is part of the Mill Creek Watershed, which is one of the subwatersheds that contribute to the Cuyahoga River. Mill Creek collects drainage from a 20 square mile area with 27.9% of that area being Garfield Heights. Currently land use statistics show that 83% of the land area within the watershed has been developed with medium density residential accounting for 62% (NEORSD, 2009).

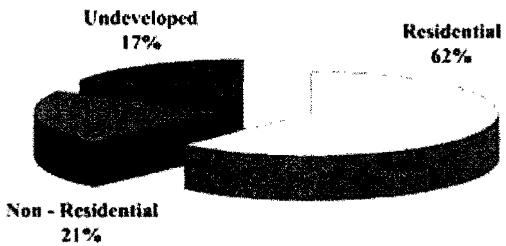

Figure 12.6 Land use for Mill Creek Watershed
(www.neorsd.com)

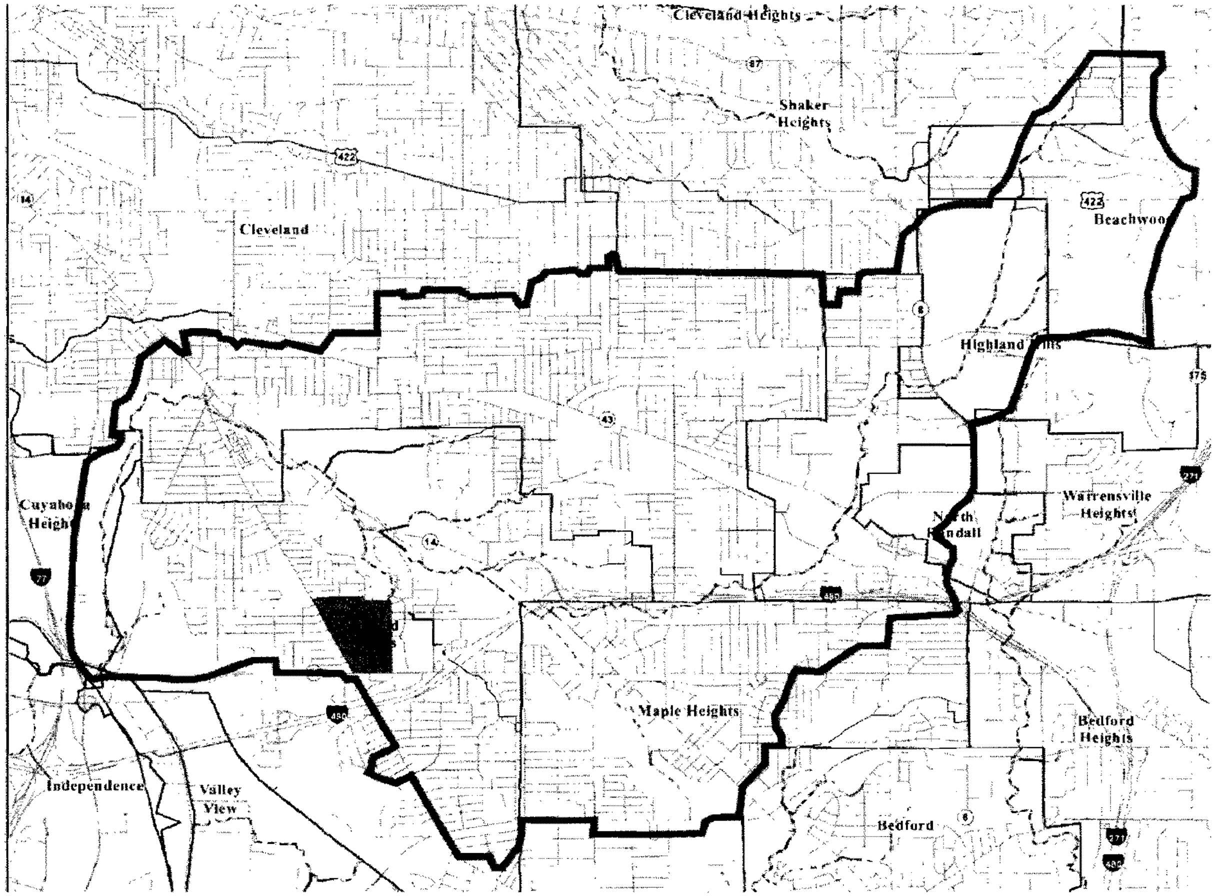

Figure 12.7 Mill Creek Watershed Boundary, Site Location Highlighted in Blue
(www.neorsd.com)

A portion of the undeveloped land area, Garfield Park, is located on the northern boundary of the project site. A total of 20 CSO are located within the Mill Creek Watershed, which has led to recent grey infrastructure projects, including the Mill Creek Project at a price of over $85 million.

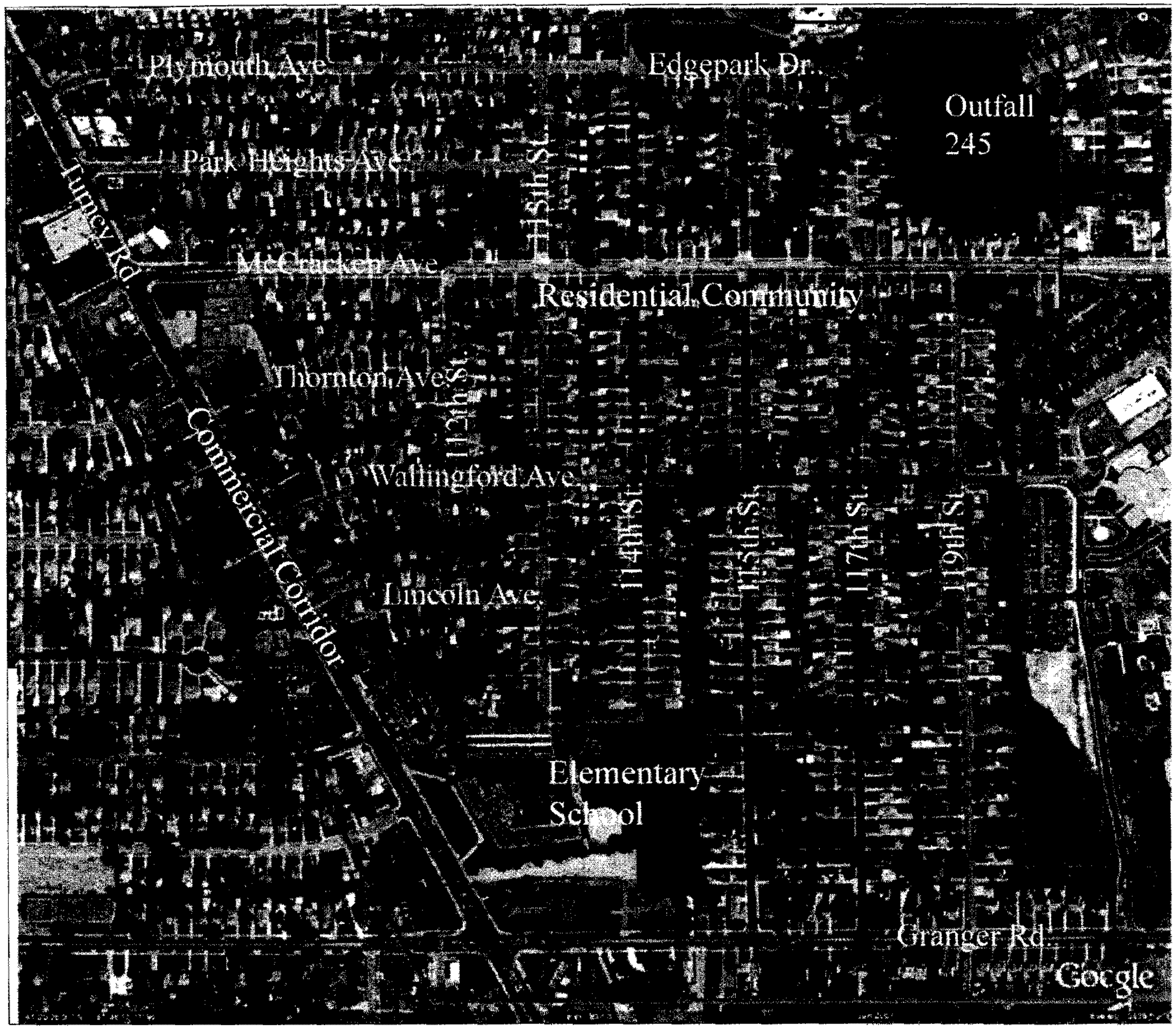

Figure 12.8 Garfield Heights Community Site Inventory

Outfall 245 is located in Garfield Park along Wolf Creek, a tributary of Mill Creek. Wolf Creek emerges from a culverted waterway into a stream at the southern point of Garfield Park due to the Marymount Hospital development to the east of the site.

52 overflow events occur annually from Outfall 245, which equates to roughly once every eight days. The 150 acre residential community adjacent to the outfall location provides the ideal location to implement Best Management Practices for the reduction of direct stormwater runoff from the community.

The majority of the site is zoned residential with a commercial corridor on the western border along Turney Road, and an Elementary School located on the corner of Turney and Granger Roads. A significant portion of the student population walks through the community going to and from school making pedestrian safety an even more significant goal.

A multitude of site factors contribute to the overall character of a site and the intended design and function of a project. Analysis of the existing environmental characteristics of the Garfield Heights site dictates the level of required alteration to the landscape in order for Green Infrastructure to be successful.

Site slope, soil permeability and frost potential are only a few of the design factors that must be considered when implementing functional Green Infrastructure projects

Environmental site investigation includes analysis of:

- Topography
- Hydrology
- Soil
- Winter Impact

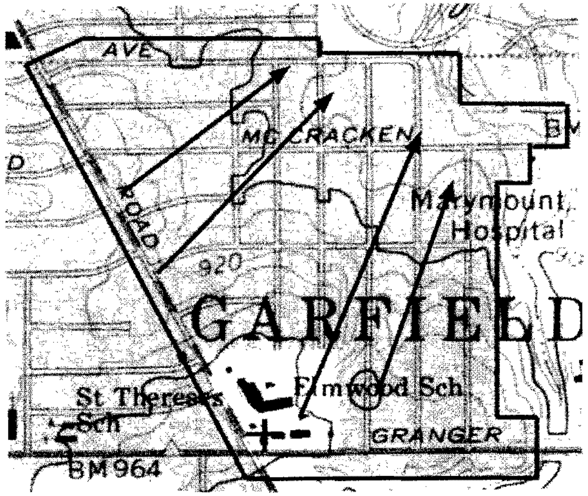

Figure 13.1a Topography & Surface Flow Map

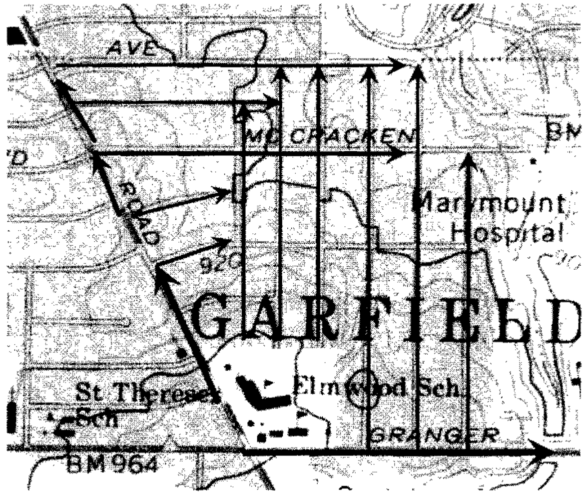

Figure 13.1b Roadway Hydrology Flow

Topography of the site slopes from the southwest to northeast corner terminating near Outfall 245. Over the 2,700 linear feet from southwest to northeast corners, a 70 foot drop occurs, which equates to a 2.6% cross-site slope.

A 2.6% slope is a beneficial trait to the site ensuring the velocity of stormwater runoff does not increase to the point where Green Infrastructure practices would be unable to allow proper infiltration and retention.

Hydrology of the site follows the existing infrastructure of impervious surfaces. Residential lots are elevated as high as three feet above the right of ways allowing any excessive runoff from the private land to flow into the public right of way. Runoff that enters the right of way follows the sloping roadways north until a drop inlet is reached allowing stormwater to ultimately enter the CSS.

Sd :nalysis

The site soil must perform two functions to ensure a successful degree of Green Infrastructure from the design. The soil must be able to sustain plant life, and transfer stormwater through its medium to the subsurface water table.

The soil should be able to maintain new native plants within an urban environment that entails increased pollution and solar stresses. Soil amendment may be required to sustain the increased plant life, but the quality should be at a point where annual fertilization would be unnecessary. The ability of the soil to transmit stormwater through its horizon at a high rate will ultimately determine the success of the project. The higher the soil conductivity, the fewer Green Infrastructure projects will be needed to address the quantity of stormwater being generated. The soil types found on the site are:

Percentage of Site	Soil Type Abbreviation	Soil Type
43%	UmB	Urban Mahoning
29.6%	LuC	Loudonville
8.2%	EIB, EsC	Ellsworth
6.7%	UnB	Urban Mitiwanga
2.5%	DkF	Dekalb

Table 13.1 Site Soil Types

	Water Capacity (cm's/cm)	Saturated Hydraulic Conductivity (microm/sec)	Drainage Class	Hydrologic Soil Group	Depth to Other Soil (cm)	Acres
DkF	.15	82.3	Well Drained	B	77	4
UnB	-	-	-	-	>200	8
EsC	.13	1.83	Moderately Well Drained	C	>200	30
LuC	.15	8.88	Well Drained	C	77	48
UmB	-	-	-	-	>200	60

Table 13.2 Site Soil Characteristics Table

Water Capacity refers to the potential water storage of a soil given in centimeters of water per centimeter of soil for each soil layer. Soil storage allows for plant growth and increased overall Green Infrastructure potential. Plant selection would be based on potential soil retention throughout the year. The ability of a soil to transmit water through its medium, expressed in terms of micrometers per second, gives the infiltration potential of the site. The higher the saturated conductivity, the greater storage potential of Green Infrastructure projects.

Drainage class refers to the frequency and duration of wet periods a certain soil allows for. Well drained assumes standing water seldom occurs due to adequate subsurface storage and infiltration. Hydraulic soil group describes the potential for runoff from a certain soil. The soils on site experience average levels of runoff from storm events once the soil has become completely saturated.

A full Soil Series Description and Soil Qualities analysis can be found in Appendix B.

Wl r Impact

A unique characteristic of the Midwest, and something other regions of the United States do not have to deal with, is the potential for frost and freezing soil. Green Infrastructure projects function above the typical frostline, a minimum of 12 inches below grade. and likewise must account for snow load, and increased stress from street salting.

The winter months will have some affect on a soils ability to hold and transmit stormwater. However a flow performance-based assessment out of Washington D.C. has revealed that the impact on infiltration of Green Infrastructure projects is minimal enough to not warrant concern (Avelleneda et. al. 2008, p. 3).

Cleveland receives on average 40" of snowfall a year, a public concern that must be plowed for safety. Snowfall is considered a wastewater especially with the addition of street salt. The implementation of Green Infrastructure projects can be viewed as a benefit by providing street locations where snow could be plowed and allowed to slowly infiltrate back into the ground.

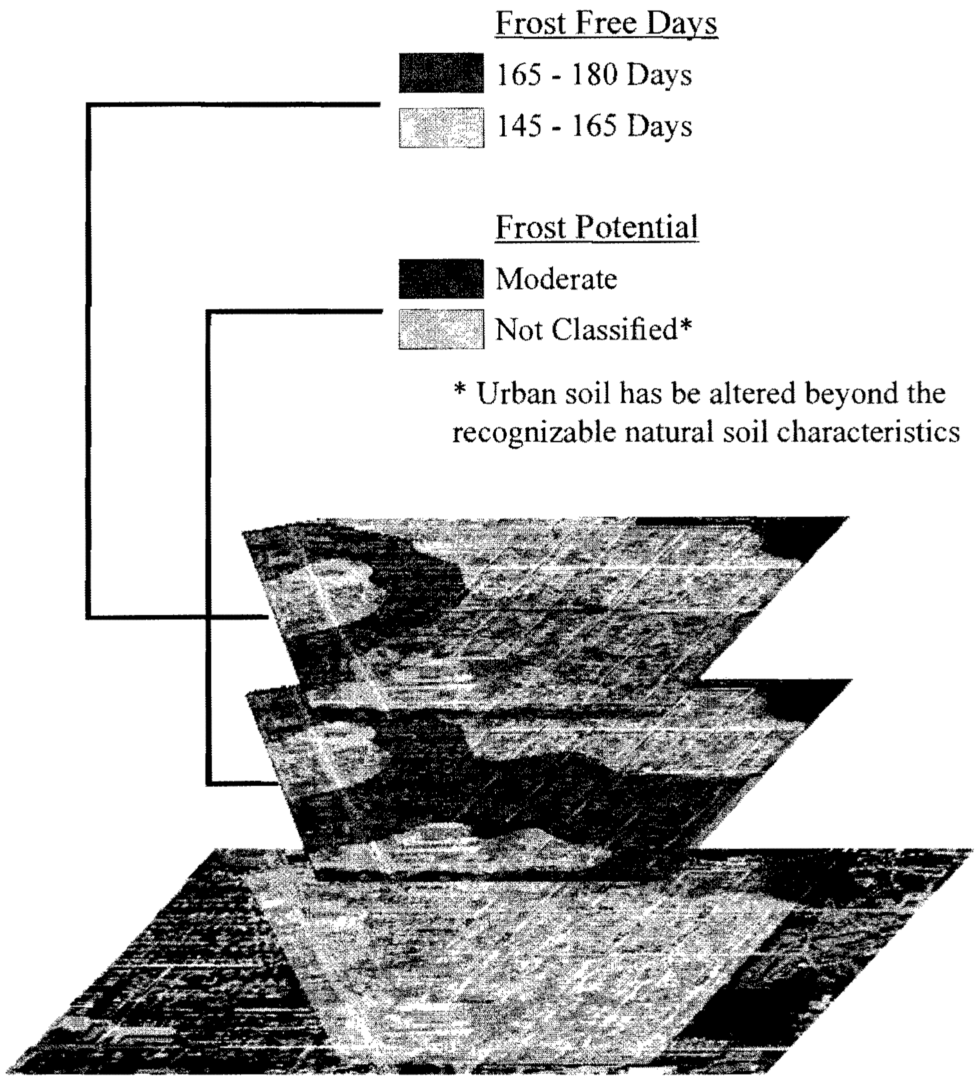

Figure 13.2 Winter Soil Characteristics

XI INVESTIGATION OF IMPERVIOUS SURFAC S

The makeup of the Garfield Heights community is important in understanding to extent of stormwater that is being generated by the impervious surface of the community. Impervious surface offers negligible infiltration capabilities for rainfall to work its way back into the ground thereby increasing the demand of retention on site by the quantity of impervious surface. With this analysis, I have broken the site down into its main hardscaped components and separated them between the private and public realms of influence.

NOTE: As designated by the Garfield Heights Planning Zoning Code, Comprehensive Stormwater Management Section 1170.09 Performance Standards, all future designs must use a **.75 inch** rain event as the minimum design rainfall level.

Figure 14.1 Site Map

Public

1.Roadways- The street grid of the community is the main component of transportation and conveyance of stormwater, and is likewise the largest location for influence capable from the city of Garfield Heights when they begin Green Infrastructure installations.

2.Sidewalks- The main pedestrian movement through the site. The sidewalk defines the edge of the public right of way and boundary between public and private land.

Private

3.Driveways- The connection between the roadway and the household, it is the impervious connection of the system between public and private stormwater.

4.Residential Rooftops- The combined surface area of the household and the garage. Rooftops represent the first points of contact between rainfall and the earth, and likewise provide a separation from the rainfall and the various pollutants and particles found on the roadway and household surfaces.

5.Commercial Development- The commercial stretch of Turney Road incorporates both the surface parking and building rooftop areas.

Public Right of Way Analysis

Roadway Name	Length *(feet)*	Width *(feet)*	Total Sidewalk Surface* *(square feet)*	Total Roadway Surface *(square feet)*	Sidewalk Stormwater Generation *(cubic feet)*	Total Roadway Stormwater Generation *(cubic feet)*
Plymouth Ave.	1,720	24	16,950	41,280	1,059	2,580
Park Heights Ave.	1,330	24	13,175	31,920	823	1,995
McCracken Ave.	2,400	30	22,625	72,000	1,414	4,500
Thornton Ave.	715	24	7,150	17,160	447	1,073
Wallingford Ave.	2,210	24	20,725	53,040	1,295	3,315
Lincoln Ave.	635	24	6,350	15,240	397	953
Elmwood Ave.	265	24	2,650	6,360	166	398
119th St.	1,925	25	19,000	48,125	1,188	3,008
117th St.	1,920	25	18,950	48,000	1,184	3,000
115th St.	2,485	25	24,300	62,125	1,519	3,883
114th St.	1,860	25	18,050	46,500	1,128	2,906
113th St.	1,870	23	17,900	43,010	1,119	2,688
112th St.	880	25	8,375	22,000	523	1,375
Turney Rd.	2,750	55	25,875	151,250	1,617	9,453
Granger Rd.	1,375	30	13,125	41,250	820	2,578
Edgepark Dr.	1,190	23	11,775	27,370	736	1,711

* Sidewalks zoned at 5' width, both sides of street

Total Sidewalk Impervious Surface	246,975 sq ft
Total Roadway Impervious Surface	726,630 sq ft
Total Impervious Surface	**973,605** sq ft
Total Sidewalk Stormwater Generation	15,436 cu ft
Total Roadway Stormwater Generation	45,414 cu ft
Total Stormwater Generation	**60,850** cu ft

Public Right of Way Analysis

	Roadways	
11%	Surface Area	726,630 sq ft
	Stormwater Generation	**45,414 cu ft**
	Sidewalks	
4%	Surface Area	246,975 sq ft
	Stormwater Generation	**15,435 cu ft**

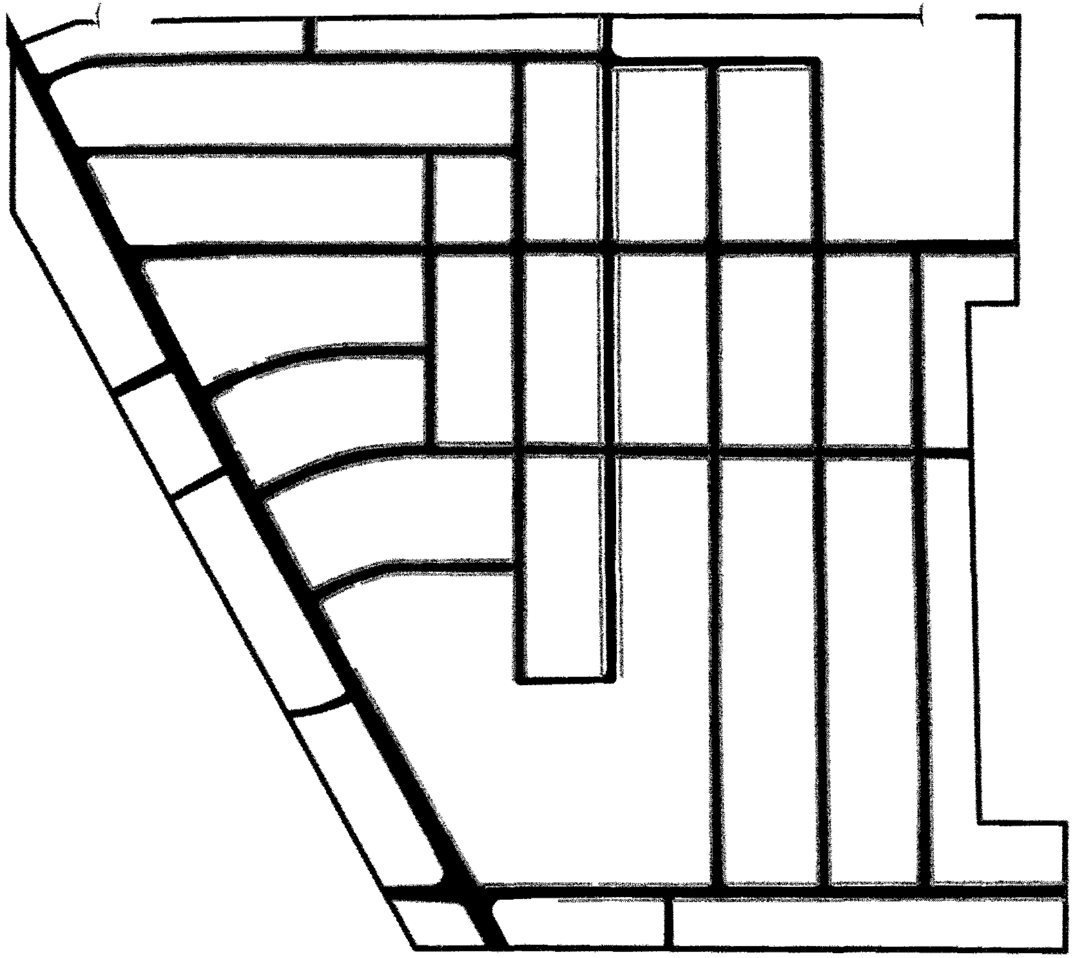

Figure 14.2

Private Driveway Analysis

Roadway Corridor	Driveways	Driveway Length* *(feet)*	Driveway Width *(feet)*	Total Driveway Surface *(square feet)*	Total Driveway Stormwater Generation *(cubic feet)*
Plymouth Ave.	65	100	8	52,000	3,250
Park Heights Ave.	49	107	8	41,944	2,622
McCracken Ave.	77	105	8	64,680	4,043
Thornton Ave.	18	115	8	16,560	1,035
Wallingford Ave.	17	95	8	12,920	808
Lincoln Ave.	16	90	8	11,520	720
119th St.	73	100	8	58,400	3,650
117th St.	77	115	8	70,840	4,428
115th St.	95	110	8	83,600	5,225
114th St.	76	115	8	69,920	4,370
113th St.	69	95	8	52,440	3,278
112th St.	19	95	8	14,440	903
Turney Rd.	12	120	8	11,520	720
Granger Rd.	48	110	8	42,240	2,640
Edgepark Dr.	24	110	8	21,120	1,320

* Average length for street corridor

Total Driveway Surface Area	624,144 sq ft
Total Driveway Stormwater Generation	**39,009** cu ft

Private Driveway Analysis

	Roadways	
11%	Surface Area	726,630 sq ft
	Stormwater Generation	**45,414 cu ft**
	Sidewalks	
4%	Surface Area	246,975 sq ft
	Stormwater Generation	**15,435 cu ft**
	Driveways	
9.5%	Surface Area	624,144 sq ft
	Stormwater Generation	**39,009 cu ft**

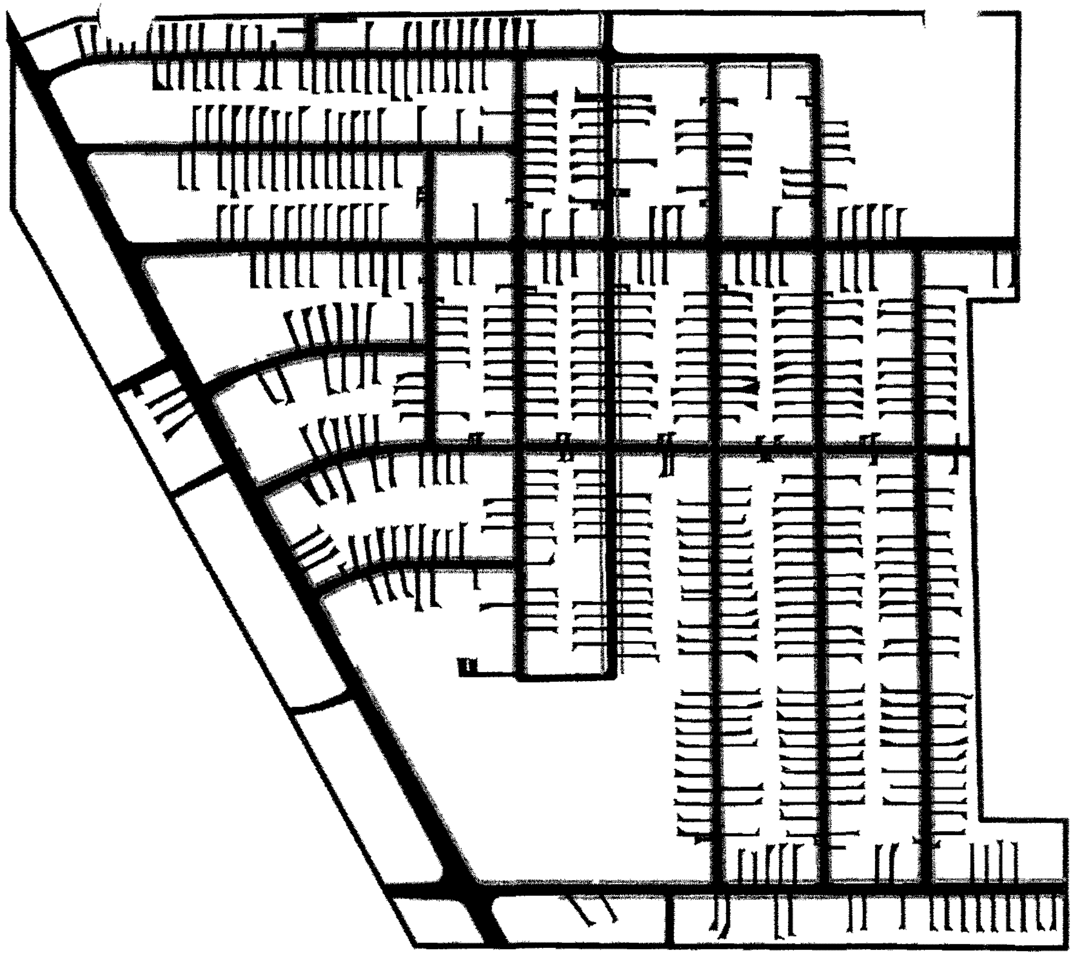

Figure 14.3

Private Residence Analysis

Roadway Corridor	House Total U1	House Total U2	Garage Total	Total House Surface* (square feet)	Total Garage Surface** (square feet)	Total House Stormwater Generation (cubic feet)	Total Garage Stormwater Generation (cubic feet)
Plymouth Ave.	-	65	65	74,750	19,500	4,672	1,219
Park Heights Ave.	-	49	49	56,350	14,700	3,522	919
McCracken Ave.	32	45	77	88,550	23,100	5,534	1,444
Thornton Ave.	18	-	18	20,700	5,400	1,294	338
Wallingford Ave.	17	-	17	19,550	5,100	1,222	319
Lincoln Ave.	16	-	16	18,400	4,800	1,150	300
119th St.	73	-	73	83,950	21,900	5,247	1,369
117th St.	77	-	77	88,550	23,100	5,534	1,444
115th St.	77	18	95	109,250	28,500	6,828	1,781
114th St.	55	21	76	87,400	22,800	5,463	1,425
113th St.	52	17	69	79,350	20,700	4,959	1,294
112th St.	19	-	19	21,850	5,700	1,366	356
Turney Rd.	12	-	12	13,800	3,600	863	225
Granger Rd.	48	-	48	55,200	14,400	3,450	900
Edgepark Dr.	-	24	24	27,600	7,200	1,725	450

* Average Household Size - 1,150 sq ft
** Average Garage Size - 300 sq ft

Total Garage Impervious Surface	220,500 sq ft
Total Household Impervious Surface	845,250 sq ft
Total Impervious Surface	**1,065,750** sq ft
Total Garage Stormwater Generation	13,781 cu ft
Total Household Stormwater Generation	52,828 cu ft
Total Stormwater Generation	**66,609** cu ft

Private Residence Analysis

	Roadways	
11%	Surface Area	726,630 sq ft
	Stormwater Generation	**45,414 cu ft**
	Sidewalks	
4%	Surface Area	246,975 sq ft
	Stormwater Generation	**15,435 cu ft**
	Driveways	
9.5%	Surface Area	624,144 sq ft
	Stormwater Generation	**39,009 cu ft**
	Residential Rooftops	
16%	Surface Area	1.065,750 sq ft
	Stormwater Generation	**66,609 cu ft**

Figure 14.4

Commercial Surface Analysis

Commercial Block	Rooftops	Total Rooftop Surface Area *(square feet)*	Parking Surface Area *(square feet)*	Total Rooftop Stormwater Generation *(cubic feet)*	Total Parking Stormwater Generation *(cubic feet)*
1	1	4,825	7,186	302	449
2	2	12,725	2,406	795	150
3	5	6,146	17,974	384	1,123
4	2	14,588	36,305	912	2,269
5	2	3,844	15,844	240	990
6	4	9,522	34,489	595	2,156
7	5	34,123	94,309	2,133	5,894
8	1	2,319	16,627	145	1,039
9	1	1,086	19,746	68	1,234
10	4	13,518	32,212	845	2,013
11	6	10,763	32,306	673	2,019
12	3	16,389	65,696	1,024	4,106

Total Rooftop Impervious Surface	129,848	sq ft
Total Parking Impervious Surface	375,100	sq ft
Total Impervious Surface	**504,948**	sq ft
Total Rooftop Stormwater Generation	8,116	cu ft
Total Parking Stormwater Generation	23,444	cu ft
Total Stormwater Generation	**31,559**	cu ft

Total Surface Analysis

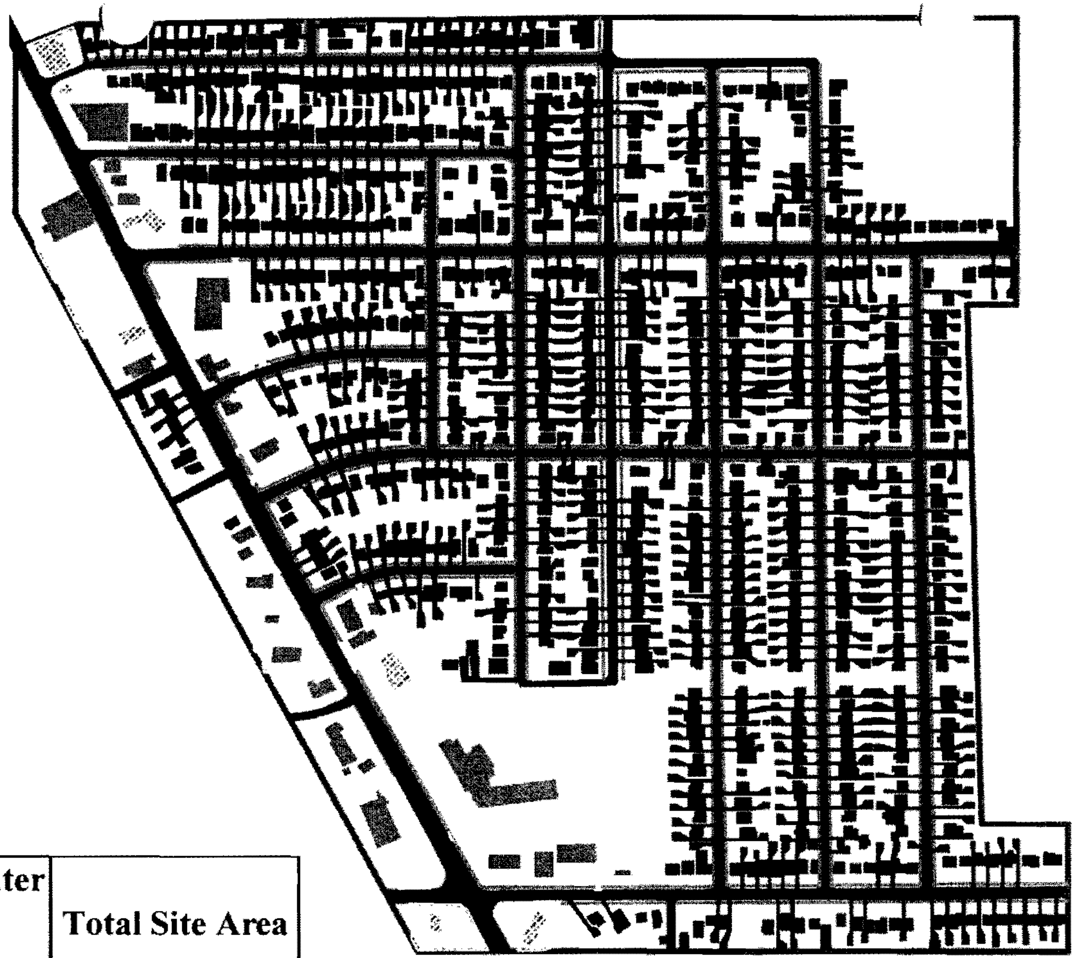

Figure 14.5

Impervious Surface Type	Total Surface Area (square feet)	Total Stormwater Generation *(cubic feet)*	Total Site Area
Roadway	726,630	45,414	11%
Sidewalk	246,975	15,436	4%
Driveway	624,144	39,009	10%
Residential Rooftop	845,250	52,828	13%
Garage Rooftop	220,500	13,781	3%
Commercial Rooftop	129,840	8,115	2%
Parking Lot	375,100	23,444	6%
Total	**3,168,439**	**198,027**	**49%**

Street Corridor Stormwater Generation

Roadway Corridor	Roadway *(cubic feet)*	Sidewalk *(cubic feet)*	Driveway *(cubic feet)*	Residents *(cubic feet)*	Garages *(cubic feet)*	Total *(cubic feet)*
Plymouth Ave.	2,580	1,060	3,250	4,673	1,218	12,781
Park Heights Ave.	1,995	825	2,622	3,523	918	9,883
McCracken Ave.	4,500	1,415	4,046	5,534	1,443	16,938
Thornton Ave.	1,072	446	1,035	1,293	337	4,183
Wallingford Ave.	3,315	1,295	810	1,225	318	6,963
Lincoln Ave.	952	396	720	1,150	300	3,518
Elmwood Ave.	397	165	-	-	-	562
119th St.	3,007	1,187	3,650	5,250	1,368	14,461
117th St.	3,000	1,184	4,427	5,534	1,443	15,588
115th St.	3,882	1,518	5,225	6,828	1,781	19,234
114th St.	2,906	1,130	4,370	5,463	1,425	15,294
113th St.	2,688	1,120	3,277	4,959	1,293	13,337
112th St.	1,375	523	902	1,365	356	4,521
Granger Rd.	2,578	820	2,640	3,450	900	10,388
Edgepark Dr.	1,710	736	1,320	1,725	450	5,941
					Total Residential Stormwater Generation	153,592 cu ft

Roadway Corridor	Roadway *(cubic feet)*	Sidewalk *(cubic feet)*	Building *(cubic feet)*	Parking *(cubic feet)*	Residnence* *(cubic feet)*	Total *(cubic feet)*
Turney Rd.	9,453	1,617	8,115	23,443	1,807	44,435
					Total Commercial Stormwater Generation	44,435 cu ft

XI ANNUAL STORMWATER GENERATION

It can be difficult to comprehend the quantity of generated stormwater spread over a 150 acre site. A .75" rainfall is capable of leaving 1,481,344 gallons of stormwater on the impervious surfaces of Garfield Heights destined for the CSS.

Table 15.2 displays the monthly rainfall levels of Cleveland, which peaks during the summer month of June. The average annual rainfall level for Cleveland is 38" with an average of 40" of snowfall a year.
(40" of snowmelt equals roughly 4" of water).

Figure 15.1 Bracken Library, Ball State University (www.msn.com)

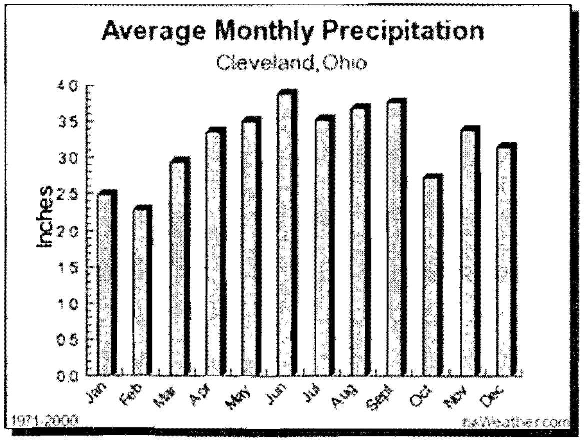

Table 15.1 Cleveland Annual Precipitation

To understand the quantity of annual rainfall on the Garfield Heights community, a graphic scale will be applied. Figure 15.1 is an aerial image of the five story Bracken Library, located on the campus of Ball State University, Indiana.

The structure will be used to measure against the annual rainfall level, but first the amount of annual stormwater generation must be computed.

Qu. .tifying Water

Average Annual Stormwater Generation for Garfield Heights Community

10,218,215 cu ft

76,437,562 gallons

76,437,562 gallons of stormwater can be understood once related to Figure 15.2. The library's dimensions of 215' by 350' and a 70' height accounts for just over half of the total annual stormwater generation.

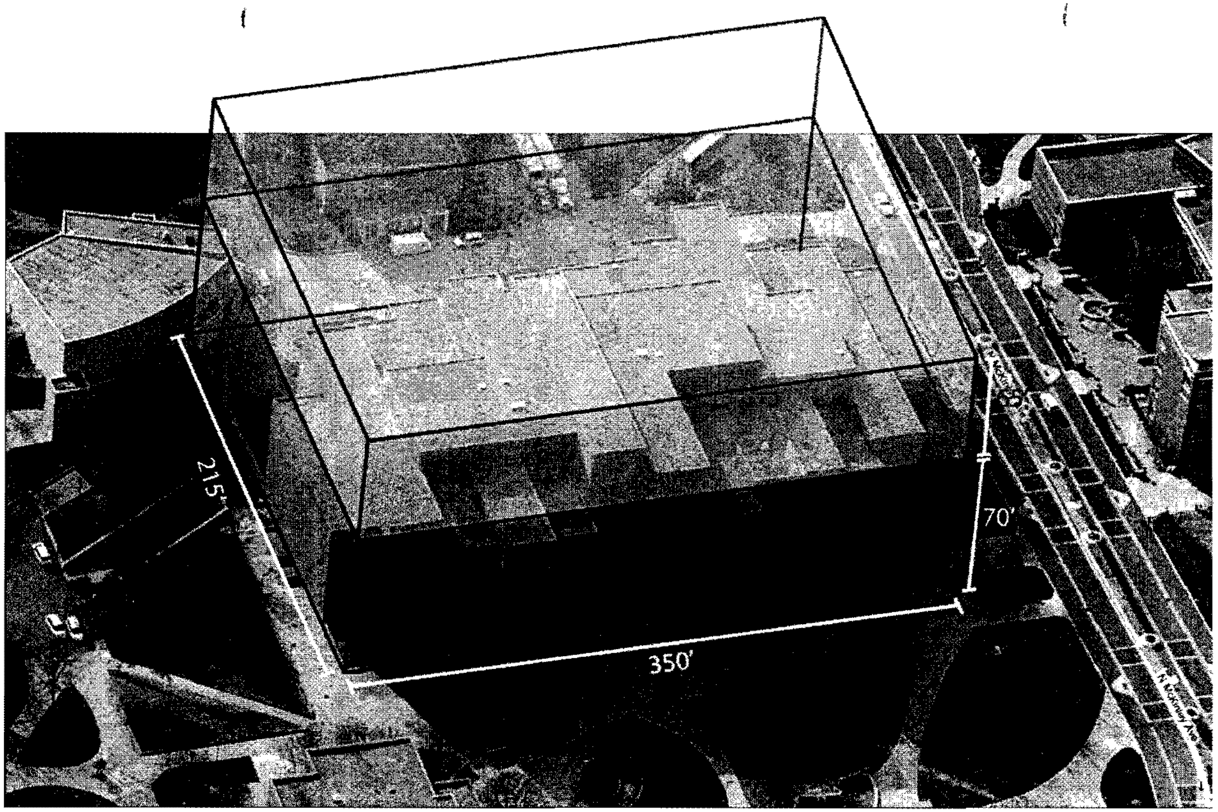

Figure 15.2 Annual Site Rainfall Volume w/ Brakcen

Rainfall Levels

Analysis of Chicago, a similar Midwest city, revealed that 98% of storm events for the city are 2" or less events. The vast majority of stormwater flowing over impervious surfaces are the result of small scale events. This presents a strong benefit of Green Infrastructure practices that have an elastic response to stormwater demand allowing the system to fluctuate with the rainfall event.

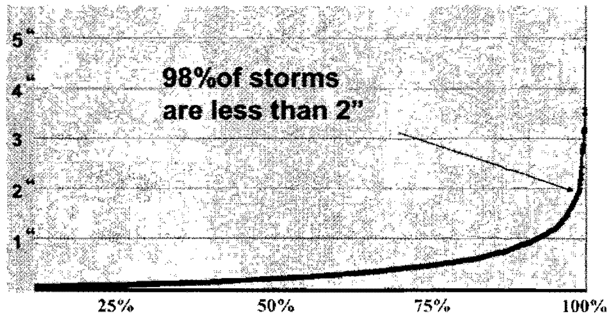

Table 15.2 Rainfall Level Percentages for Chicago
(Camarata, p. 12)

XV Right of Way Analysis

The public right of way, from sidewalk to sidewalk, presents the optimal, low impact location for a design focus. Design philosophy is based on Low Impact Development (LID) with minimal disturbance to the existing private infrastructure of the site.

The linear potential of the site ties in with the current stormwater runoff from the site along the public right of way with design working itself into the parking lane area of the roadway.

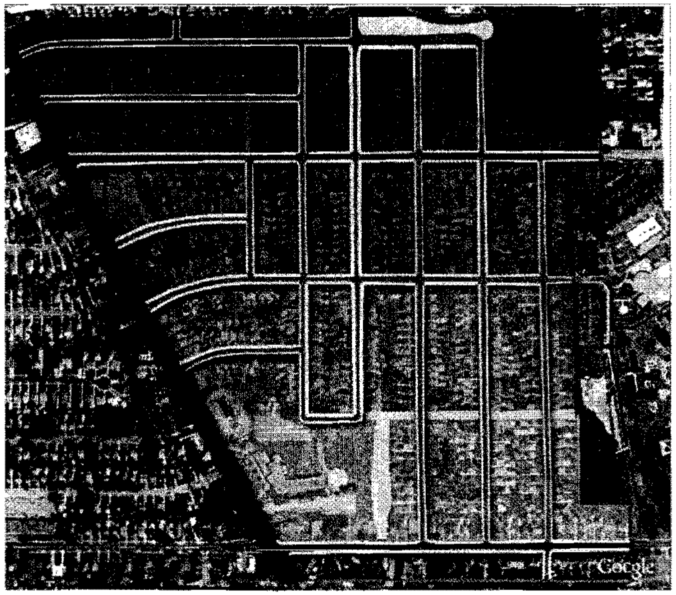

Figure 16.1 Low Impact Development Realm of Influence

Type A Roadway	
Drive Lane	18'
Parking Lane	7'
Sidewalk	5'
Tree Lawn	**12'**
Building Setback	45'

Total right of way width: 59'

24' of tree lawn width presents the most options of all the street types for design area of influence.

Type B Roadway	
Drive Lane	18'
Parking Lane	7'
Sidewalk	5'
Tree Lawn	**6'**
Building Setback	30'

Total right of way width: 47'

12' of tree lawn width still allows for effective design space for Green Infrastructure projects.

Type C Roadway	
Drive Lane	18'
Parking Lane	7'
Sidewalk	5'
Tree Lawn	**2'**
Building Setback	25'

Total right of way width: 39'

The narrowest of the public right of ways, 4' width of total tree lawn still allows for the 7' parking lane to be utilized for curb bumpouts

XV Type A Roadway

All residential streets maintain the same roadway width of 25’ while being flanked by two sidewalks with a 5’ width per sidewalk. The variation of street types therefore comes down to tree lawn widths and building setbacks from the roadway with Type A Roadways exhibiting the widest expanse.

Figure 17.3 Type A Roadway Vicinity Map

The red highlighted region in Figure 17.2 refers to the Type A Roadway Design block along 114th St. (see Chapter XXV.)

Type A Roadways
114th Street
Edgepark Drive

Two of the residential streets qualify for Type A designation. Such roads as McCracken and Turney Road were not considered for classification due to the use intensity of the roadways and lack of residential street quality to promote community growth.

Figure 17.1 114th St. Existing Conditions

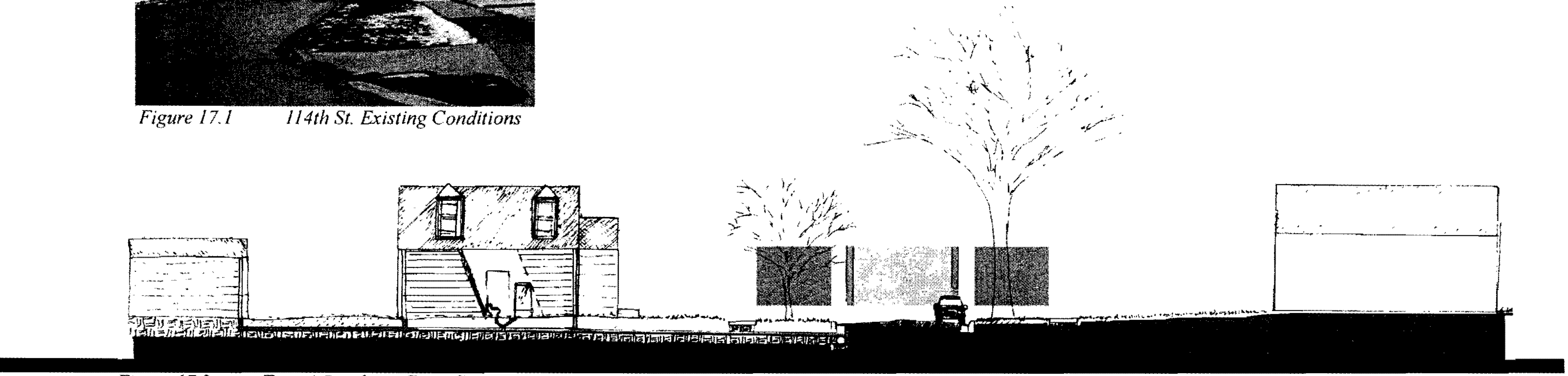

Figure 17.2 Type A Roadway Cross Section

XVIII. Type B Roadway

Type B Roadways still allow for moderately large public project installations to increase the retention and infiltration potential of the roadways.

Public Projects include:

Curb Bumpouts- extension of the tree lawn space into the parking lane of a roadway in order to capture roadway stormwater.

Swale Retention- Depressed tree lawn areas which allow for storage and eventual infiltration of excess stormwater runoff.

Figure 18.1 Thornton Ave. Existing Conditions

Figure 18.2 Type B Roadway Vicinity Map

The red highlighted region in Figure 18.2 refers to the Type B Roadway Design block along Thornton Ave. (see Chapter XXVI.)

Type B Roadways
Thornton Avenue
Wallingford Avenue
Lincoln Avenue

Type B Roadways comprise the majority of east-west streets across the site. The connection to the busy commercial corridor of Turney Road allows for numerous gateway opportunities demarcating an entrance into the residential community.

XII Type C Roadway

The tighter width of Type C Roadways carries with it a limitation on the storage potential per installation due to only having 2' width tree lawns. However, the space enjoys the close proximity of homes making community enhancement more likely to stretch across the right of way.

Figure 19.3 Type C Roadway Vicinity Map

The red highlighted region in Figure 19.3 refers to the Type C Roadway Design block along 117th. St. (see Chapter XXVII.)

Type C Roadways
119th Street
117th Street
115th Street
113th Street
112th Street
Plymouth Avenue
Park Heights Avenue

Figure 19.1 117th. St. Existing Conditions

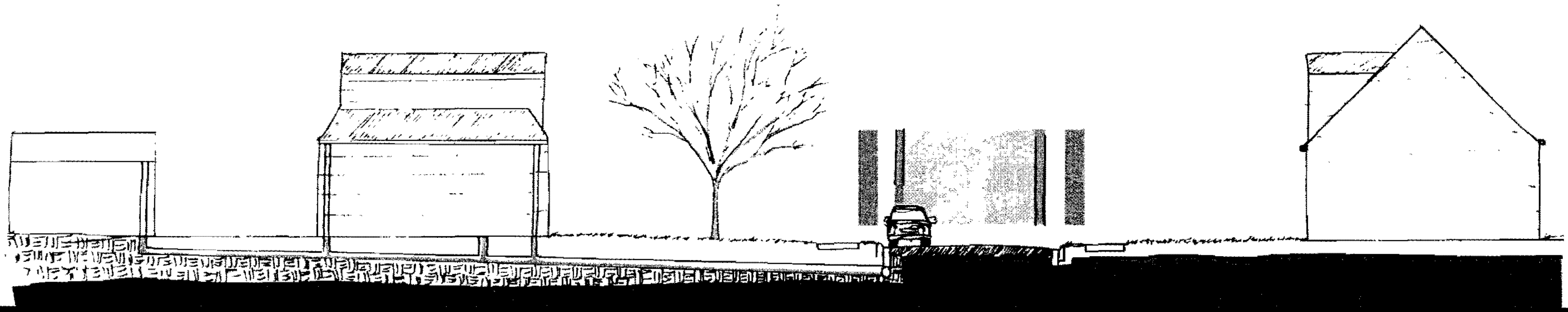

Figure 19.2 Type C Roadway Cross Section

XX Zoning Investigation

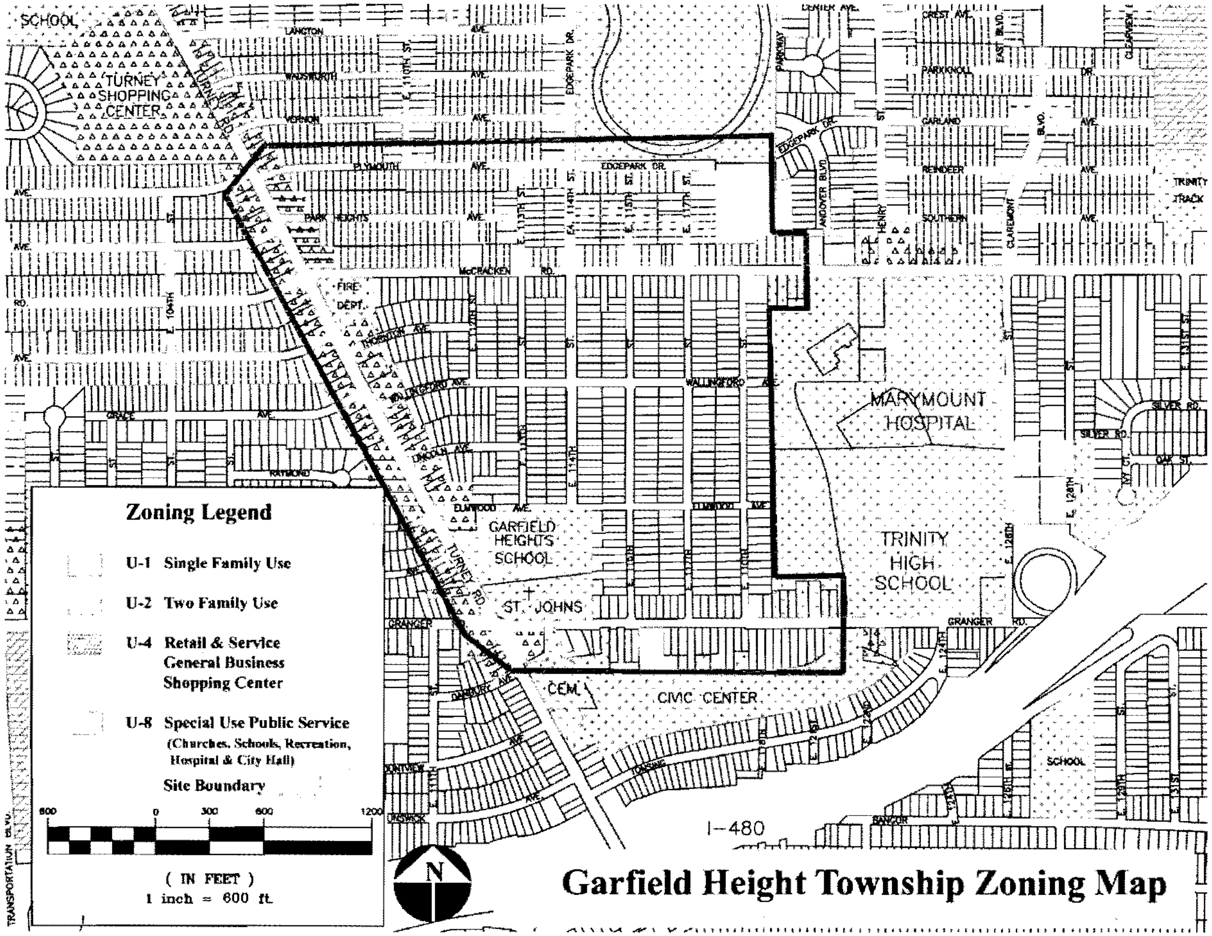

Figure 20.1 Garfield Heights Zoning Map
(www.garfieldhts.org)

The site is comprised of four zoned area types.

Single Family Use- Largely concentrated to the south of McCracken St., single family use comprises the majority of the site area

Two Family Use- Situated to the north of McCracken St., the larger home style lends a different quality to the community.

* There are a total of **735** housing lots on the site

Retail & Service - Commercial land use is only located along Turney Road, the western border to the site.

Special Use Public Service- Special uses include an elementary school and Fire Station along Turney Road, and Garfield Park located to the northeast of the site.

XXI Type 1 Residence

Type 1 housing consists of two family housing units. Due to the larger residence sizes on Type 1 lots, there is a higher level of generated stormwater from the impervious surface coupled with the decreased infiltration potential of the porous lawn spaces.

Type 1 characteristics, as seen in Table 21.1, show that there is more impervious surface on the lot than pervious and that the rooftop is more than twice the size of the front lawn. Addressing stormwater runoff will require high intensity projects, such as rain gardens and porous pavement, to account for potential runoff along with the low intensity measures of rain barrels and lawn infiltration.

Type 1 Lot Size	
	(sq ft)
Lawn Area	2,142
Impervious Area	2,233
Total Area	4,375
Lawn:Impervious Ratio	0.96
Front Lawn	540
Rootop Area	1125
Front Lawn:Rooftop Ratio	0.48

Table 21.1 Type 1 Lot Characteristics

Figure 21.1 Type 1 Lot Location Map

Type 1 housing differs from types 2 & 3 due to its zoning. It is the only two family use lots on site, which are all located to the north of McCracken Avenue.

Aside from their larger size, house character matches the quality of the neighborhood.

Figure 21.2 Type 1 Residence, corner of McCracken & 117th St.

XXI Type 2 Residence

A majority of the site is comprised of Type 2 housing units. They are zoned single family use just as Type 3 units are. The main difference lies in housing style. Compared to Type 3, the roof area is larger while the character of the house has more pitched roofs as in Figure 22.2.

Stormwater from Type 2 Residences, though smaller than Type 1, will still require some high intensity rain garden installations along with the low intensity projects.

Lawn to impervious surface area begins to grow with Type 2 units, which aides the infiltration potential of the residences.

Figure 22.1 Type 2 Lot Location Map

Type 2 units follow the main north-south streets of the site. They are the main housing type to the north of Wallingford Avenue, and continue south following 117th, 115th, & 114th Streets to Granger Road.

Type 2 Lot Size	
	(sq ft)
Lawn Area	3,445
Impervious Area	2,252
Total Area	5,697
Lawn:Impervious Ratio	1.53
Front Lawn	1,400
Rootop Area	900
Front Lawn:Rooftop Ratio	1.56

Table 22.1 Type 2 Lot Characteristics

Figure 22.2 Type 2 Residence along 114th Street

XX I. Type 3 Residence

Type 3 residences present the greatest opportunity for low impact development. The front lawn to rooftop, as determined by the Washington D.C. study (see Chapter XI: Precedent Studies, Green Buildout Model) allows for direct downspout from rooftops to infiltrate into the front lawn. This coupled with rain barrels will provide enough of an impact to reduce Type 3 stormwater runoff.

Figure 23.1 Type 2 Lot Location Map

Pockets of Type 3 residences can be identified by their compact house character. While Type 1 & 2 housing characters differ within their classifications, Type 3 units are an identical layout.

Type 3 Lot Size	
	(sq ft)
Lawn Area	3,445
Impervious Area	1,955
Total Area	5,400
Lawn:Impervious Ratio	1.76
Front Lawn	1,110
Rootop Area	675
Front Lawn:Rooftop Ratio	1.64

Table 23.1 Type 3 Lot Characteristics

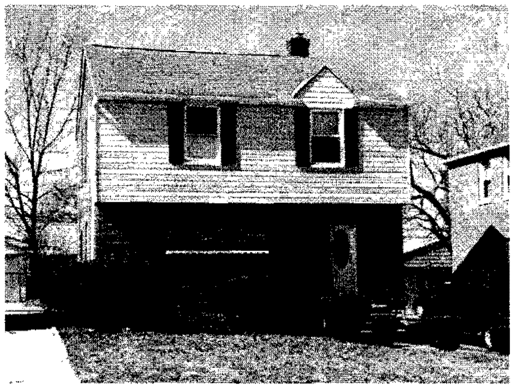

Figure 23.2 Type 3 Residence along 119th Street

Key Terms

Right of Way (ROW) - the public realm from sidewalk to sidewalk

Curb Bumpout - extension of retention basin into the roadway in order to capture roadway runoff.

Swale Storage- tree lawn detention basin designed to hold excess stormwater runoff for controlled infiltration.

Total Storage- the combined storage potential of the curb bumpouts and swale detention basin.

Rain Barrel- used to collect rooftop runoff from residential homes and garages to alleviate the need for direct downspout connections, barrel sizes range from 55-75 gallons.

Porous Pavement- an impervious infiltration strip located along the extent of driveways to account for driveway runoff.

Lawn Infiltration - the ability for a residences green space to accommodate the runoff from residential rooftops. A front yard to rooftop ratio of 1.5:1 is the required green space determined to account for rooftop runoff.

Key Assumptions: Roadway Design

Retention/Infiltration Potential- the added above and below grade storage potential of a Green Infrastructure installation. Subgrade storage is based on 20" of runoff held within the soil stratus.

Swale Storage Potential- the above grade storage potential of a tree lawn swale.

Key Assumptions: Residential Design

Raingarden Storage Potential- is based on the above ground retention plus the subgrade storage potential of 20" for a total storage depth of 26 inches

Driveway Porous Pavement Storage- a 12" storage depth is based on the 4" depth of pavement and 8" of amended subgrade.

Lawn Infiltration Potential- only implemented when there is a 2:1 Front Lawn to Roof ratio, infiltration based on 75% of the total front lawn square footage capable of infiltrating runoff with the calculated subgrade storage at 6" with the rainfall level subtracted from the potential storage depth (6"-rainfall level=subgrade storage depth)

The following pages detail three green street and three residential lot designs:

Type A ROW	114th Street
Type B ROW	Thornton Avenue
Type C ROW	117th Street

Type 1 Residence
Type 2 Residence
Type 3 Residence

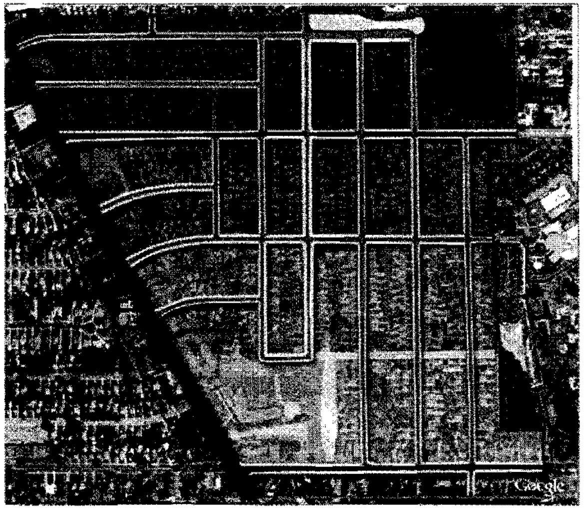

Figure 24.1 Design Realm of Influence

XI TYPE A ROADWAY - EXISTING CONDITIOI 114TH ST.
For Single Block between McCracken Ave. & Wallingford Ave.

Right of Way (ROW)

The street corridor ROW is comprised of two 9' drive lanes and a 7' parking lane along the east curb. The crested roadway sheets runoff to the curbed edges. Drop inlets are situated at the north intersection, and midpoint of the block.

12' tree lawns buffer the sidewalks from the roadway.

Hydrology

Stormwater runoff flows from south to north along the roadway. Runoff that does not enter the drop inlets at the intersection of Wallingford and 114th from the west flows into the block. The elevated residential plots likewise contribute any excessive runoff from the private property.

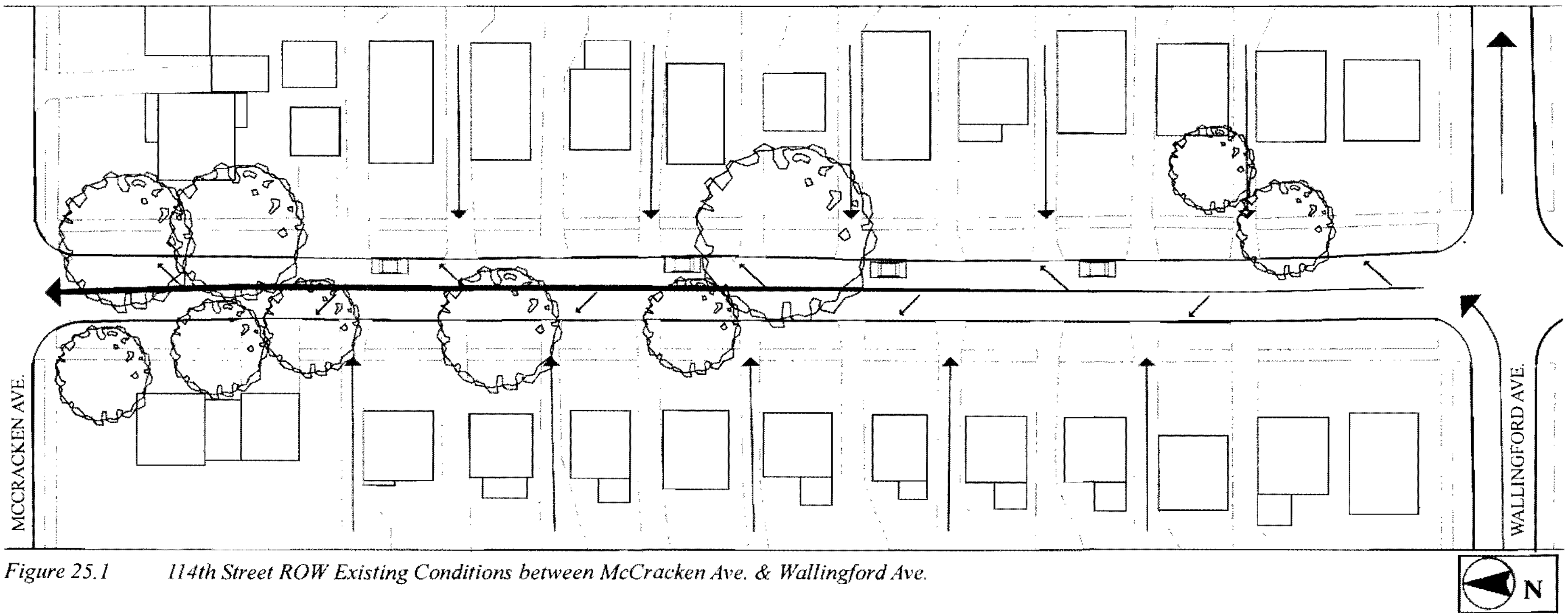

Figure 25.1 *114th Street ROW Existing Conditions between McCracken Ave. & Wallingford Ave.*

TYPE A ROADWAY - PROPOSED DESIGN 1[illegible]TH ST.

114th Street Stormwater Reduction

Rainfall Level *(in)*	<u>ROW Stormwater Generation</u> *(cu ft)*	Private Drive Stormwater Generation *(cu ft)*	ROW + Drive Stormwater Generation *(cu ft)*	Bumpout Storage Area *(sq ft)*	Projected Total Retention/Infiltration Potential* *(cu ft)*	Swale Storage Potential** *(cu ft)*	Total Projected Storage Potential*** *(cu ft)*	<u>ROW Stormwater/Storage Difference</u> *(cu ft)*	ROW + Drive Stormwater/Storage Difference *(cu ft)*
.75"	1,236	1,507	2,743	3,628	9,650	1,119	10,769	**9,533**	8,026
1"	1,648	1,994	3,642	3,628	9,650	1,119	10,769	**9,121**	7,127
1.5"	2,471	3,014	5,485	3,628	9,650	1,119	10,769	**8,298**	5,284
2"	3,295	4,019	7,314	3,628	9,650	1,119	10,769	**7,474**	3,455
3"	4,943	6,028	10,971	3,628	9,650	1,119	10,769	**5,826**	-202
4"	6,591	8,037	14,628	3,628	9,650	1,119	10,769	**4,178**	-3,859

Table 25.1 Stormwater Generation & Storage for Varying Rainfall Levels

* See page 52
** See page 52
*** The combined Swale Storage & Retention/Infiltration Potential

Summary Impact of Proposed Changes

Impervious Roadway Reduction	1,315 sq ft
Total Impervious Roadway	14,125 sq ft
Percentage Reduction	9.31%
Stormwater Reduction	82.1875 cu ft

Table 25.2 Type A Impervious Reduction

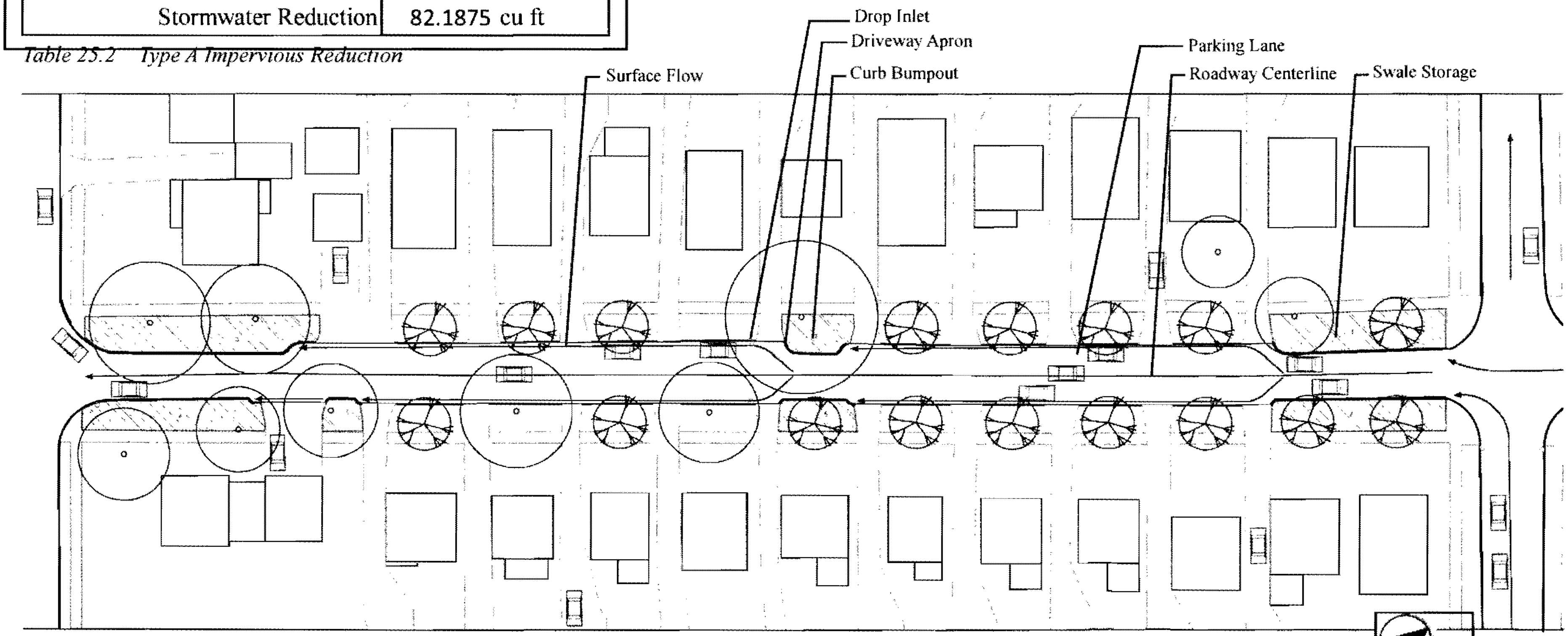

Figure 25.2 114th Street ROW Proposed Design between McCracken Ave. & Wallingford Ave.

TYPE A ROADWAY - DESIGN DETAILS 114th ST.

For Single Block between McCracken Ave. & Wallingford Ave.

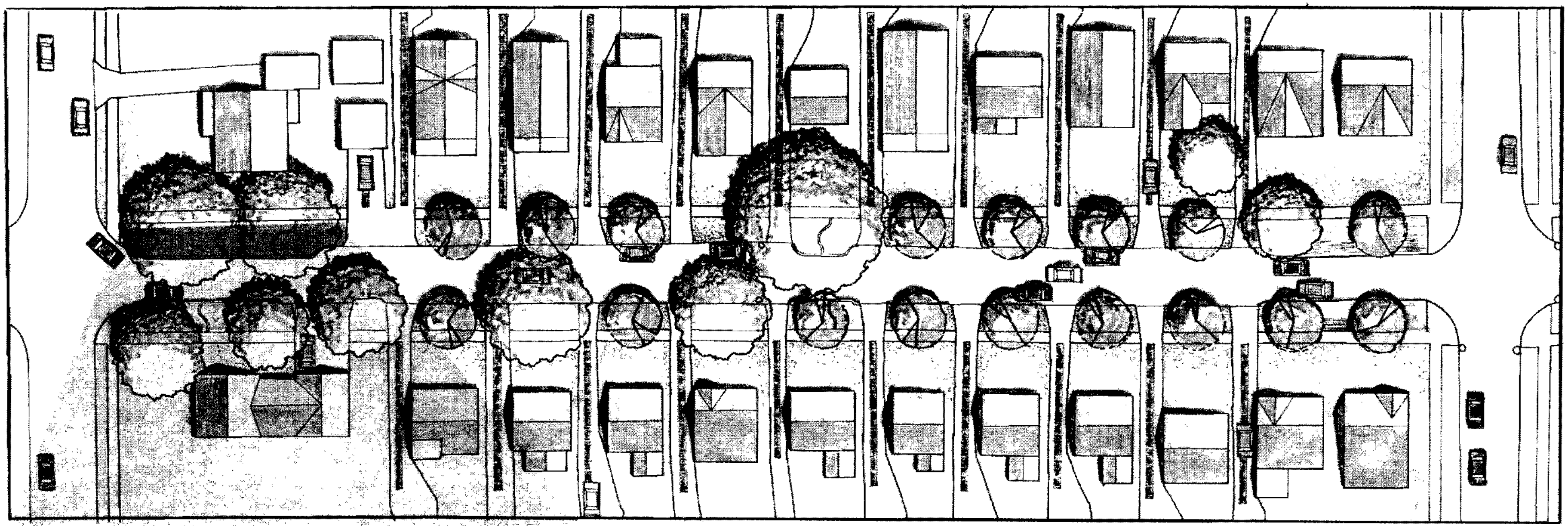

Figure 25.3 114th Street Design Detail

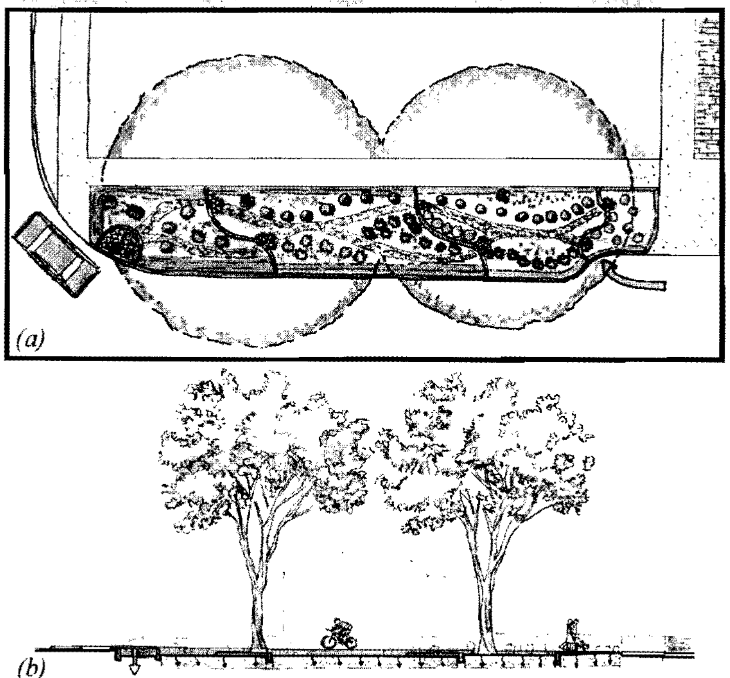

Figure 25.4 a. b 114th Street Curb Bumpout Detail

Design Elements

5 Curb Bumpouts
2 Swale Storage Basins
17 Street Trees

The altered dynamic benefits from the street front additions of garden spaces and street trees. Curb Bumpout rain gardens will add color and vitality to the street as the design aims to build a neighborhood from the roadway out.

The 114th Street design successfully accounts for storm events beyond a 2" rainfall, which accounts for 98% of annual storm events.

XXVI. TYPE B ROADWAY - EXISTING CONDITIONS THORNTON AVE.
For Single Block between Turney Rd. & 112th St.

Right of Way (ROW)

The street corridor ROW is comprised of two 9' drive lanes and a 7' parking lane along the southern curb. The crested roadway sloping from west to east sheets runoff to the curbed edges. Drop inlets are situated at the east intersection, and midpoint of the block.

6' tree lawns buffer the sidewalks from the roadway.

Hydrology

Stormwater runoff flows from west to east along the roadway. Runoff from Turney Road enters to site from the western intersection. The elevated residential plots likewise contribute any excessive runoff from the private property.

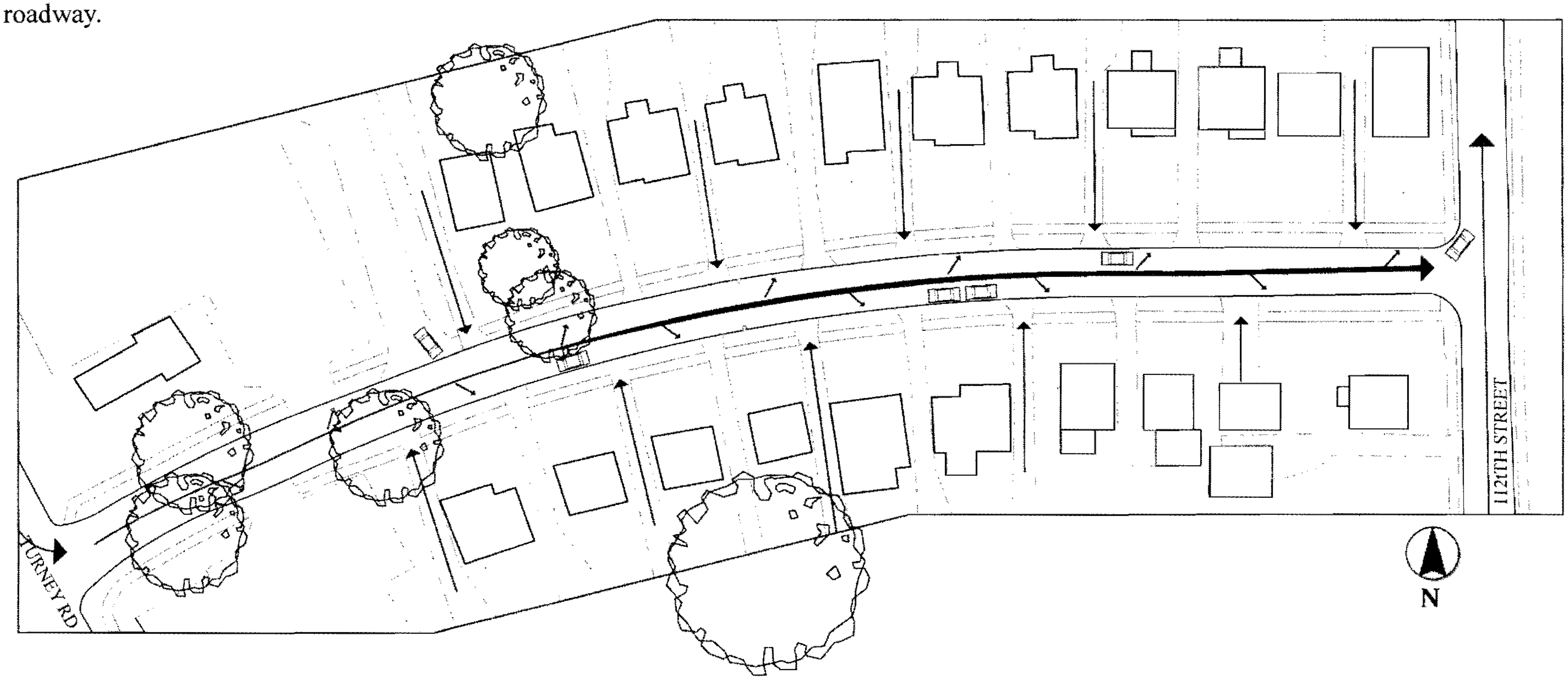

Figure 26.1 *Thornton Aveneue ROW Existing Conditions between Turney & 112th Street*

TYPE B ROADWAY - PROPOSED DESIGN TH RNTON AVE.

Thornton Avenue Stormwater Reduction

Rainfall Level *(in)*	ROW Stormwater Generation *(cu ft)*	Private Drive Stormwater Generation *(cu ft)*	ROW + Drive Stormwater Generation *(cu ft)*	Bumpout Storage *(sq ft)*	Projected Total Retention/Infiltration Potential* *(cu ft)*	Swale Storage Potential** *(cu ft)*	Total Projected Storage Potential*** *(cu ft)*	ROW Stormwater/Storage Difference *(cu ft)*	ROW + Drive Stormwater/Storage Difference *(cu ft)*
.75"	1,519	1,035	2,554	2,586	6,879	1,880	8,759	**7,240**	6,205
1"	2,026	1,380	3,406	2,586	6,879	1,880	8,759	**6,733**	5,353
1.5"	3,039	2,070	5,109	2,586	6,879	1,880	8,759	**5,720**	3,650
2"	4,052	2,760	6,812	2,586	6,879	1,880	8,759	**4,707**	1,947
3"	6,078	4,140	10,218	2,586	6,879	1,880	8,759	**2,681**	-1,459
4"	8,103	5,520	13,623	2,586	6,879	1,880	8,759	**655**	-4,865

Table 26.1 Stormwater Generation & Storage for Varying Rainfall Levels

* See page 52
** See page 52
*** The combined Swale Storage & Retention/Infiltration Potential

Summary Impact of Proposed Changes

Impervious Roadway Reduction	1,330 sq ft
Total Impervious Roadway	17,160 sq ft
Percentage Reduction	7.75%
Stormwater Reduction	83.125 cu ft

Table 26.2 Type B Impervious Reduction

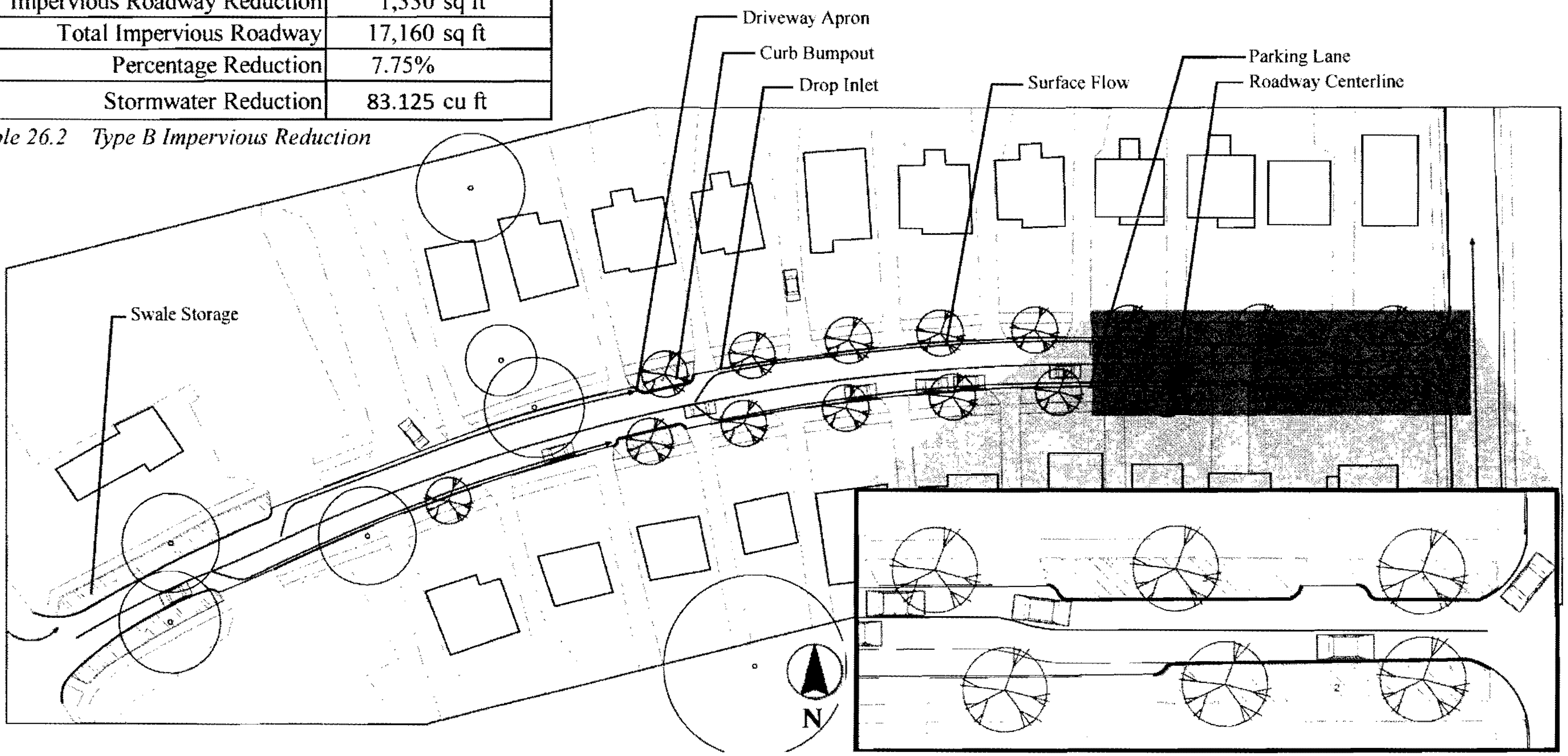

Figure 26.2 Thornton Avenue ROW Proposed Design between Turney & 112th Street

Figure 26.3 Centerline Detail

TYPE B ROADWAY - DESIGN DETAILS TH(NTON AVE.

For Single Block between Turney Rd. & 112th St.

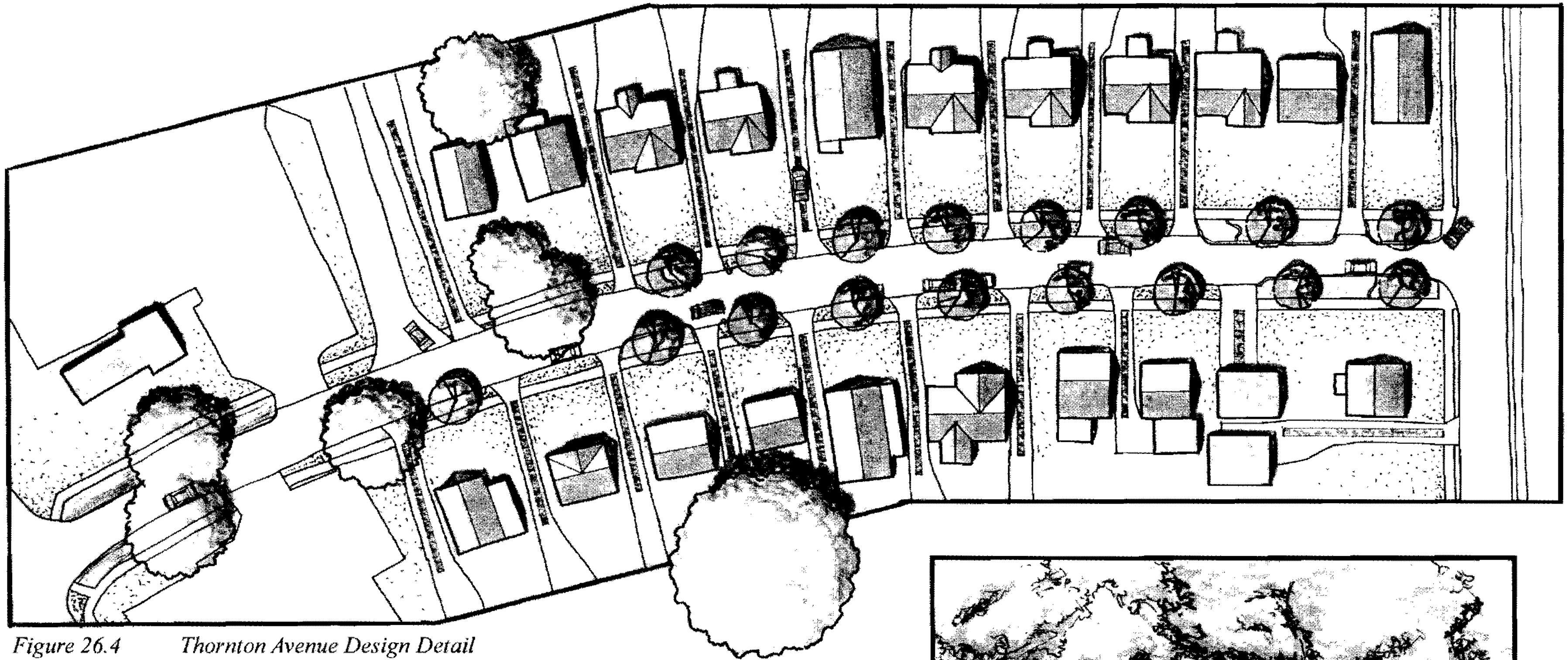

Figure 26.4 Thornton Avenue Design Detail

Thornton Avenue is one of the gateways to the community as people transfer from public to private streets coming off of Turney Road.

The Green Street benefits from curb bumpouts located next to existing drop inlets allowing for runoff retention before it reaches the CSS.

Design Elements

5 Curb Bumpouts
2 Swale Storage Basins
17 Street Trees

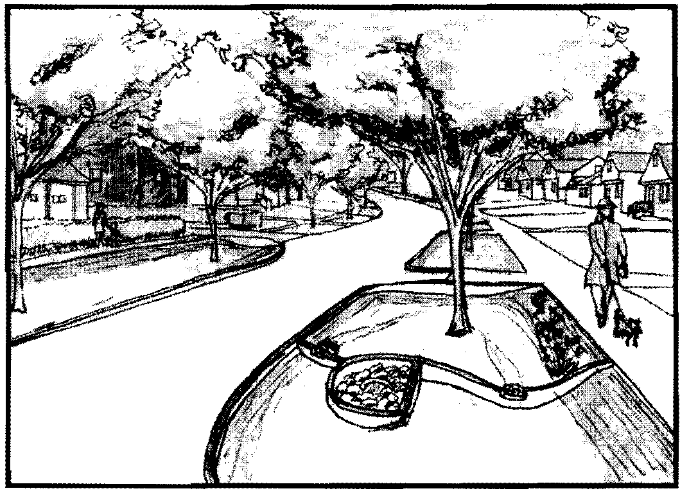

Figure 26.5 Thornton Avenue Green Street

X! II. TYPE C ROADWAY - EXISTING CONDITI NS 117TH ST.
For Single Block up to McCracken Ave.

Right of Way (ROW)

The street corridor ROW is comprised of two 9' drive lanes and a 7' parking lane along the east curb. The crested roadway sloping from south to north sheets runoff to the curbed edges. Drop inlets are situated at the north bend, and midpoint of the block.

2' tree lawns buffer the sidewalks from the roadway.

Hydrology

Stormwater runoff flows from south to north along the roadway. Runoff from McCracken Avenue enters to site from the southern intersection. The elevated residential plots likewise contribute any excessive runoff from the private property.

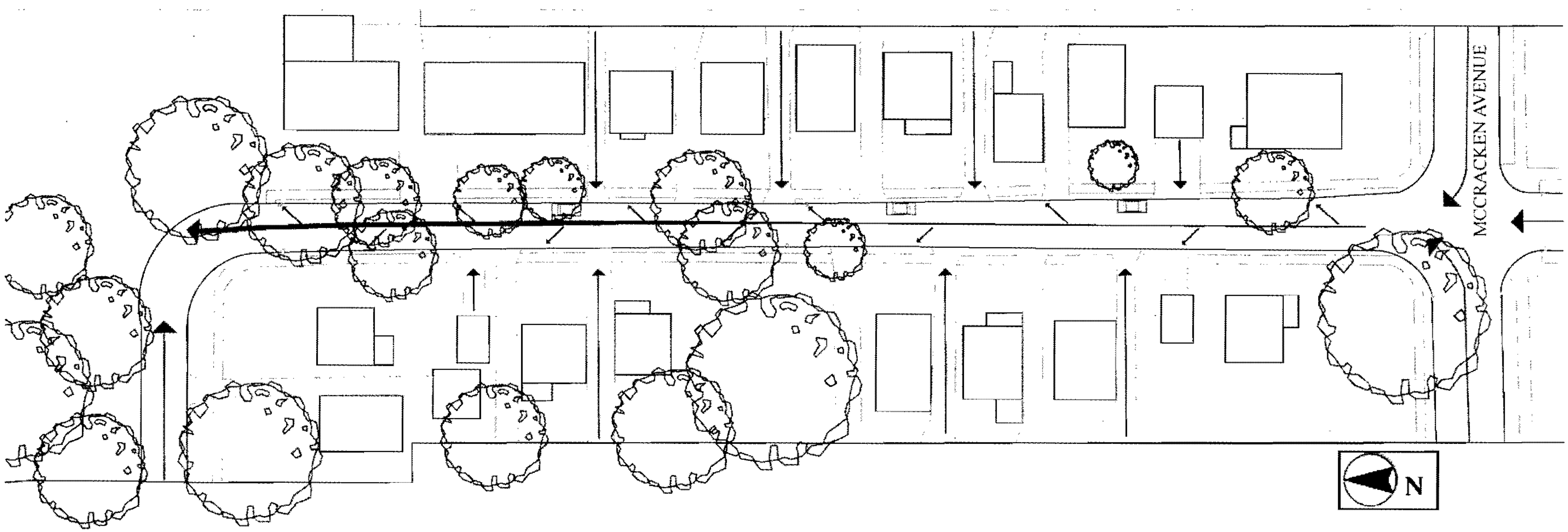

Figure 27.1 *117th Street ROW Existing Conditions up to McCracken Avenue*

117th Street Stormwater Reduction

Rainfall Level (in)	ROW Stormwater Generation (cu ft)	Private Drive Stormwater Generation (cu ft)	ROW + Drive Stormwater Generation (cu ft)	Bumpout Storage (sq ft)	Projected Total Retention/Infiltration Potential* (cu ft)	Swale Storage Potential** (cu ft)	Total Projected Storage Potential*** (cu ft)	ROW Stormwater/Storage Difference (cu ft)	ROW + Drive Stormwater/Storage Difference (cu ft)
.75"	1,445	935	2,380	2,868	7,629	5,724	13,353	**11,908**	10,973
1"	1,927	1,247	3,174	2,868	7,629	5,724	13,353	**11,426**	10,179
1.5"	2,891	1,870	4,761	2,868	7,629	5,724	13,353	**10,462**	8,592
2"	3,854	2,493	6,348	2,868	7,629	5,724	13,353	**9,499**	7,005
3"	5,781	3,740	9,521	2,868	7,629	5,724	13,353	**7,572**	3,832
4"	7,708	4,987	12,695	2,868	7,629	5,724	13,353	**5,645**	658

Table 27.1 Stormwater Generation & Storage for Varying Rainfall Levels

* See page 52
** See page 52
*** The combined Swale Storage & Retention/Infiltration Potential

Summary Impact of Proposed Changes

Impervious Roadway Reduction	1,687 sq ft
Total Impervious Roadway	16,875 sq ft
Percentage Reduction	10.00%
Stormwater Reduction	105.4375 cu ft

Table 27.2 Type C Impervious Reduction

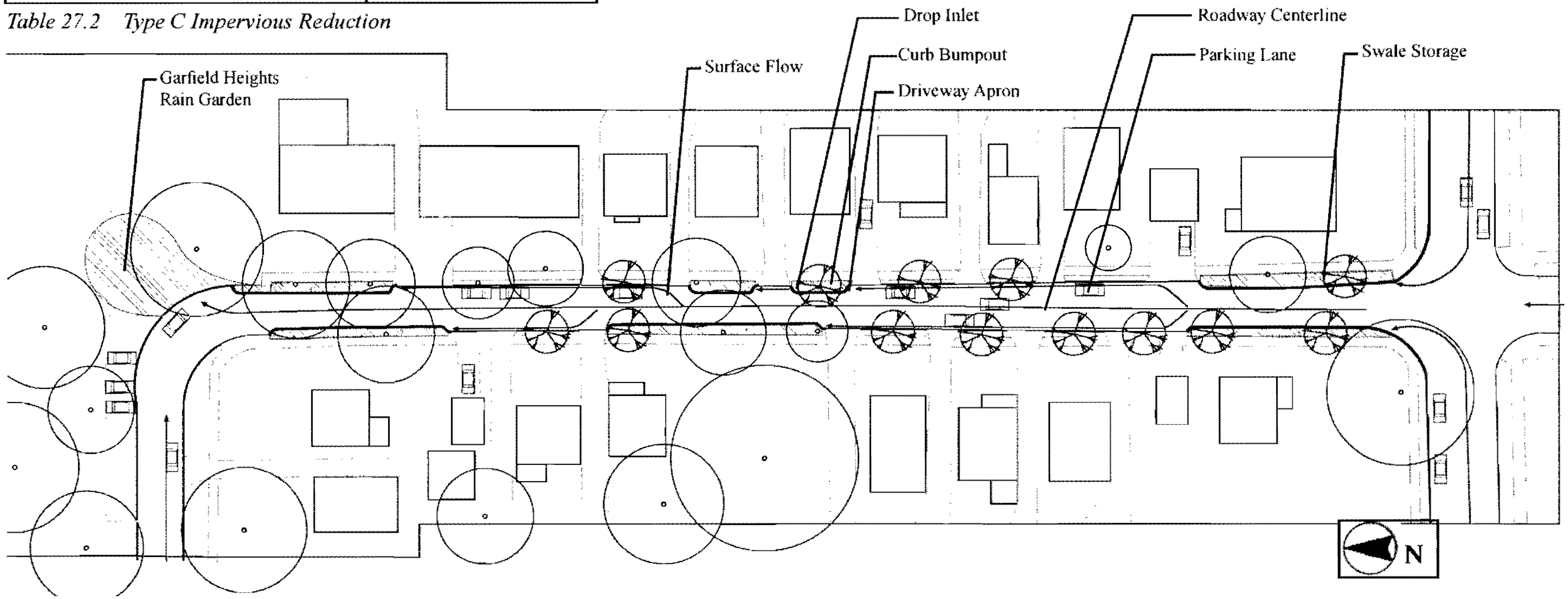

Figure 27.2 117th Street ROW Proposed Design up to McCracken Avenue

TYPE C ROADWAY - DESIGN DETAILS 117th ST.
For Single Block up to McCracken Ave.

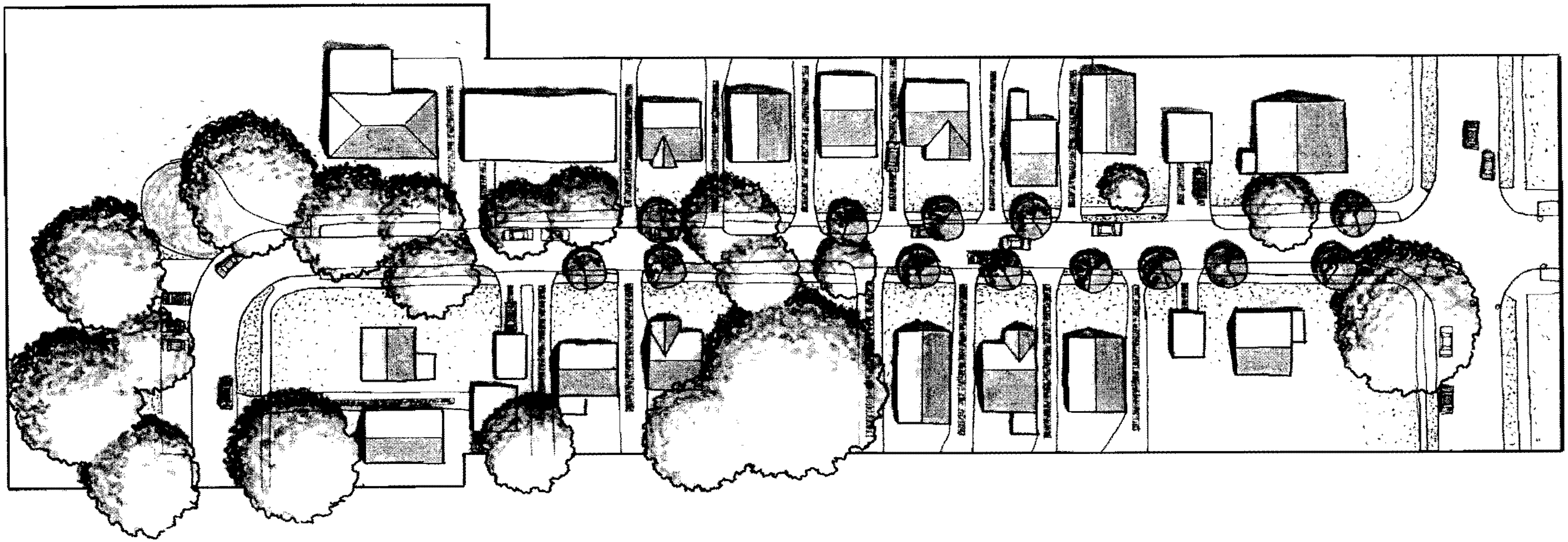

Figure 27.3 117th Street Design Detail

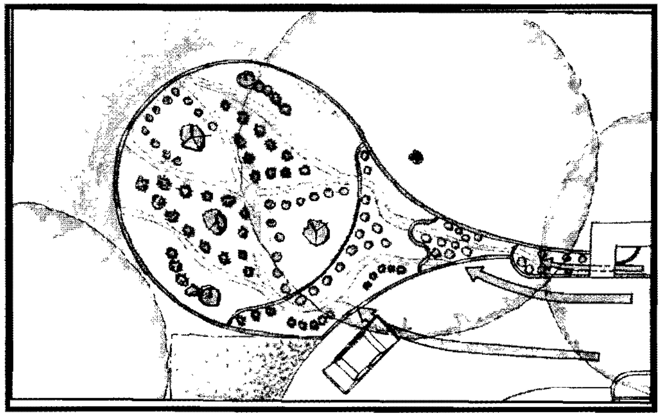

Figure 27.4 Garfield Heights Community Rain Garden

Design Elements

5 Curb Bumpouts
2 Swale Storage Basins
1 Rain Garden
13 Street Trees

The bend of 117th Street marks the northeastern point of the site and therefore the low point where surface runoff ultimately flows. Due to its elevation and location alongside Garfield Park, the bend offers the ideal location for a community rain garden, creating a public place to learn and enjoy stormwater management.

2' tree lawns dictate that curb bumpout design be long, linear retention basins. An existing infrastructure of street trees would make it an easy transition to enhance the community.

XXVIII. TYPE 1 RESIDENCE - EXISTING CONDITIONS
Along Park Heights Ave.

The Park Heights Avenue Residence generates 140 cubic feet of total impervious runoff from a .75” rainfall. The typical Type 1 Lot consists of more impervious surface than porous lawn area.

Type 1 Residential Lot- Park Heights Ave.			
	square feet	*cubic feet*	*gallons*
Garage	252	15.75	118
House	1,125	70.31	526
Driveway	856	53.5	400
Total	**2,233**	**139.56**	**1,044**

Table 28.1 Type 1 Impervious Surface Analysis

Rain Barrels

Rooftops generate the largest quantity of runoff at 85 cu ft between garage & residence. Rain barrels provide a quick and low impact result for disconnecting downspouts from the CSS.

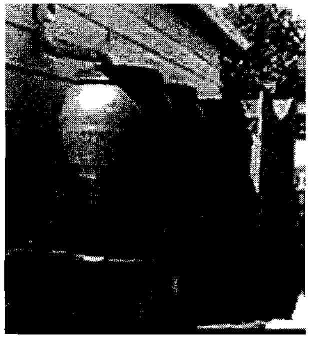

Figure 28.1 Residential Rain Garden
(Camarata, p. 43)

The barrel sizes used for residential applications are 55 gallons and 70 gallons.

Stormwater runoff from a residence comes from sheet flow from driveway surfaces to the public ROW and direct downspout connections to the CSS from rooftops. It is a benefit to be accounted for that collected runoff can be used for future residential water applications such as irrigation.

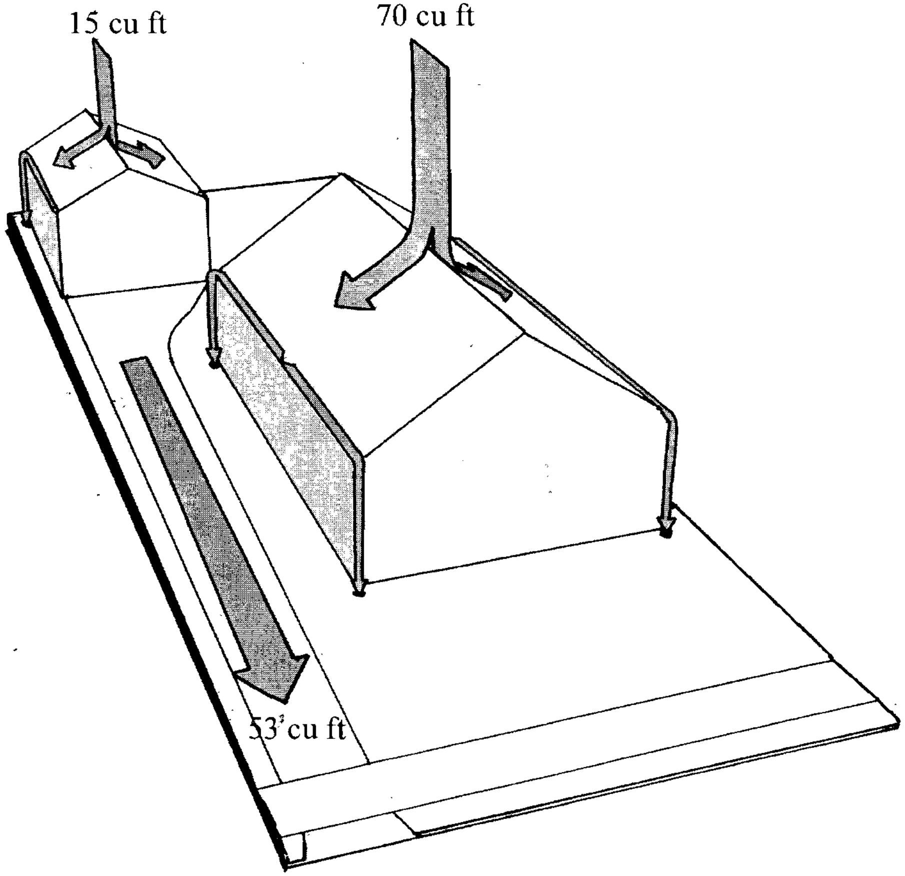

Figure 28.2 Type 1 Existing Runoff Hydrology

TYPE 1 RESIDENCE - PROPOSED GREEN INFRASTRUCTURE APPLICATIONS

Rainfall Level *(in)*	Green Infrastructure Design	Application	Number	Storage Potential *(cu ft)*	Total Runoff Potential *(cu ft)*	Stormwater Storage *(cu ft)*	Percentage Reduction	Remaining Storage Potential *(cu ft)*
0.75	Garage	Rain Barrels	2	18.72	15.75	15.75	100%	2.97
0.75	Residence	Rain Barrels	4	37.43	35.00	35.00	100%	2.43
0.75		Rain Garden	1	108.00	35.00	35.00	100%	73.00
0.75	Driveway	Porous Pavement	1	140.00	53.50	53.50	100%	86.50
		TOTAL		**304.15**	**139.25**	**139.25**	**100%**	**164.90**
1	Garage	Rain Barrels	2	18.72	21.00	18.72	89%	-2.28
1	Residence	Rain Barrels	4	37.43	46.88	37.43	80%	-9.44
1		Rain Garden	1	108.00	46.88	46.88	100%	61.13
1	Driveway	Porous Pavement	1	140.00	71.33	71.33	100%	68.67
		TOTAL		**304.15**	**186.08**	**174.35**	**94%**	**118.06**
2	Garage	Rain Barrels	2	18.72	42.00	18.72	45%	-23.28
2	Residence	Rain Barrels	4	37.43	93.75	37.43	40%	-56.32
2		Rain Garden	1	108.00	93.75	108.00	115%	14.25
2	Driveway	Porous Pavement	1	140.00	142.67	140.00	98%	-2.67
		TOTAL		**304.15**	**372.17**	**304.15**	**82%**	**-68.02**

Table 28.2 Residential Lot Stormwater Generation & Storage for Varying Rainfall Levels

TYPE 1 RESIDENCE - DESIGN DETAILS
Along Park Heights Ave.

Garage

Rain Barrels 15 cu ft

Residence

Rain Barrels 35 cu ft

Rain Garden 35 cu ft

Driveway

Porous Pavement 53 cu ft

100% Storage Potential from a .75" rainfall event

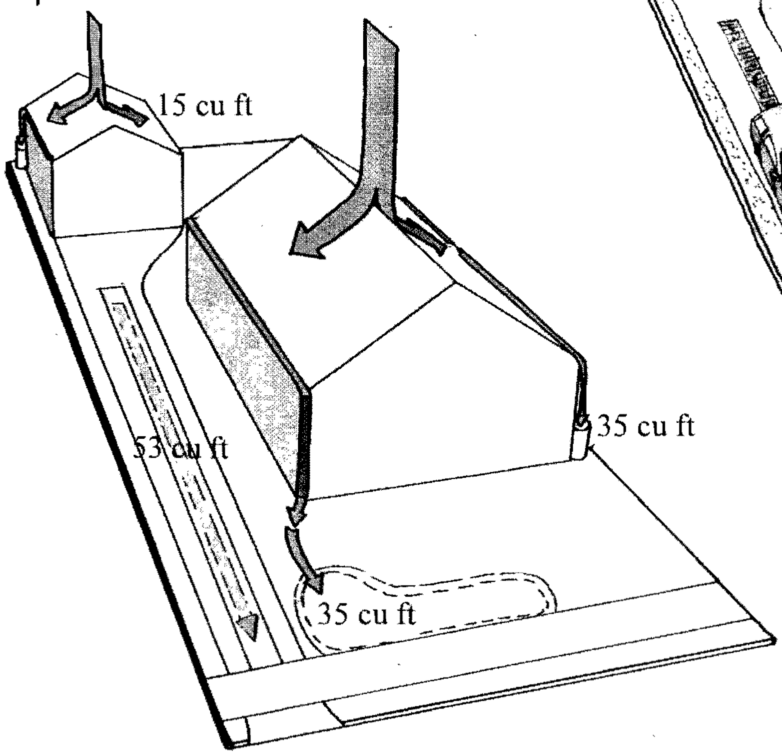

Figure 28.3 Type 1 Proposed Hydrology

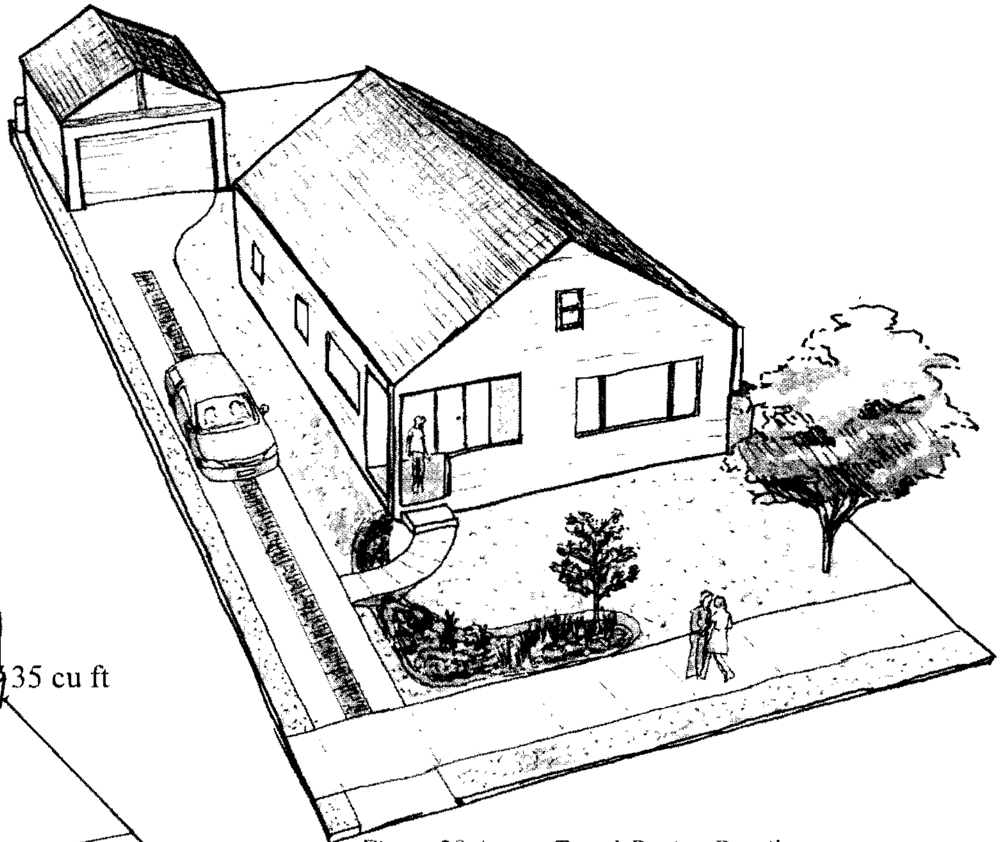

Figure 28.4 Type 1 Design Details

Green Infrastructure Application

6	Rain Barrels
1	Rain Garden (55 sq ft)
1	Porous Pavement (140 sq ft)

XXIX. TYPE 2 RESIDENCE - EXISTING CONDITIONS
Along 117th St.

The main housing type of the project site, Type 2 Residences allow for a mix of low and high impact applications. Rain barrel capture matched with lawn infiltration and rain garden installations cover the full potential of stormwater capture from a private residence

Type 2 Residential Lot- 117th St.			
	square feet	*cubic feet*	*gallons*
Garage	432	27	202
House	900	56.25	420
Driveway	920	57.5	430
Total	**2,252**	**140.75**	**1,052**

Table 29.1 Type 2 Impervious Surface Analysis

Rain Gardens

Rain gardens present a more high impact and high infiltration capability. The functional garden space located in the front yard of residence provides a uniting street feature to a community that implements a green street project.

With the elevate slope of the residences from the roadway, rain gardens also provide a final retention buffer between the private and public realm and the stormwater generated and accounted for from each.

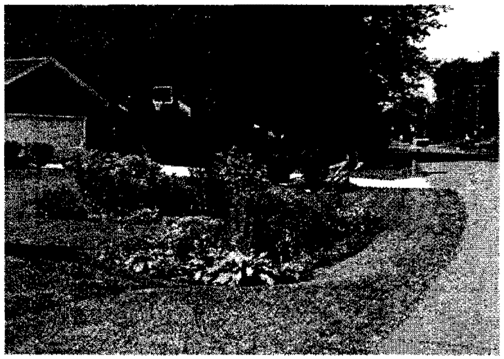

Figure 29.1 Residential Rain Garden
(www.beltramiswcd.org)

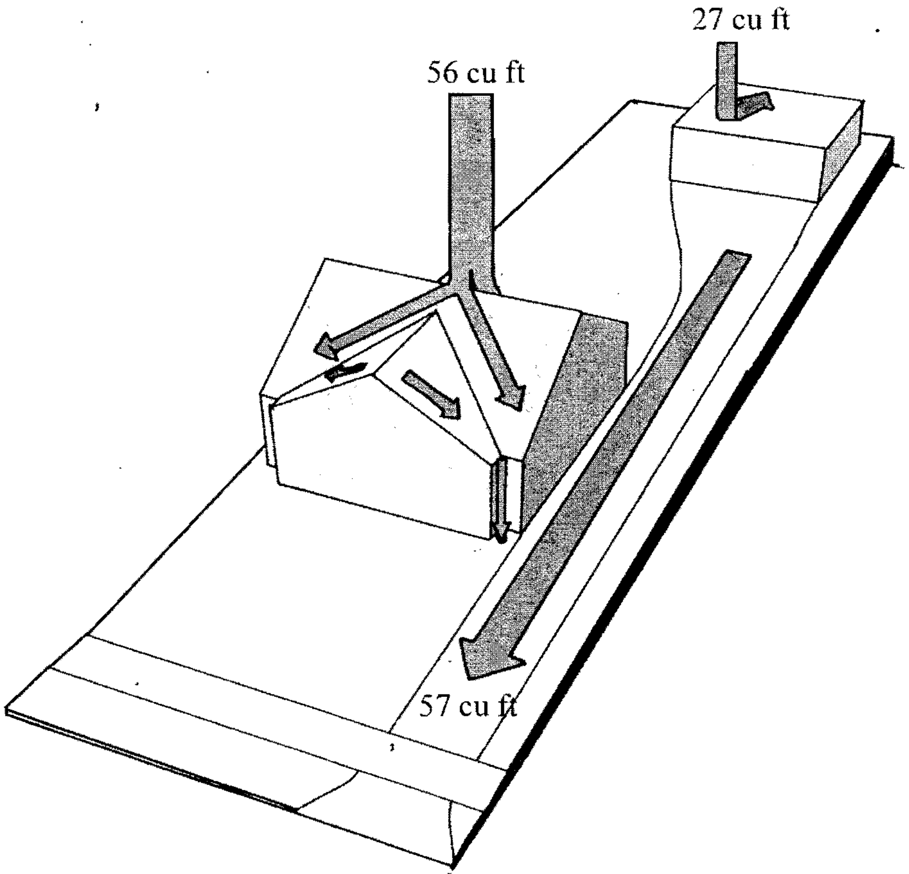

Figure 29.2 Type 2 Existing Runoff Hydrology

TYPE 2 RESIDENCE - PROPOSED GREEN INFRASTRUCTURE APPLICATIONS

Rainfall Level *(in)*	Green Infrastructure Design	Application	Number	Storage Potential *(cu ft)*	Total Runoff Potential *(cu ft)*	Stormwater Storage *(cu ft)*	Percentage Reduction	Remaining Storage Potential *(cu ft)*
0.75	Garage	Rain Barrels	4	37.43	27.00	27.00	100%	10.43
0.75	Residence	Rain Barrels	2	16.71	14.06	14.06	100%	2.65
0.75		Rain Garden	1	71.50	28.13	28.13	100%	43.38
0.75		Lawn Infiltration	1	459.38	14.06	14.06	100%	445.31
0.75	Driveway	Porous Pavement	1	140.00	57.50	57.50	100%	82.50
		TOTAL		**725.02**	**140.75**	**140.75**	**100%**	**584.27**
1	Garage	Rain Barrels	4	37.43	36.00	36.00	100%	1.43
1	Residence	Rain Barrels	2	16.71	18.75	16.71	89%	-2.04
1		Rain Garden	1	71.50	37.50	37.50	100%	34.00
1		Lawn Infiltration	1	437.50	18.75	18.75	100%	418.75
1	Driveway	Porous Pavement	1	140.00	76.67	76.67	100%	63.33
		TOTAL		**703.14**	**187.67**	**185.63**	**99%**	**515.47**
2	Garage	Rain Barrels	4	37.43	72.00	37.43	52%	-34.57
2	Residence	Rain Barrels	2	16.71	37.50	16.71	45%	-20.79
2		Rain Garden	1	71.50	75.00	71.50	95%	-3.50
2		Lawn Infiltration	1	350.00	37.50	37.50	100%	312.50
2	Driveway	Porous Pavement	1	140.00	153.33	140.00	91%	-13.33
		TOTAL		**615.64**	**375.33**	**303.14**	**81%**	**240.31**

Table 29.2 Residential Lot Stormwater Generation & Storage for Varying Rainfall Levels

TYPE 2 RESIDENCE - DESIGN DETAILS
Along 117th St.

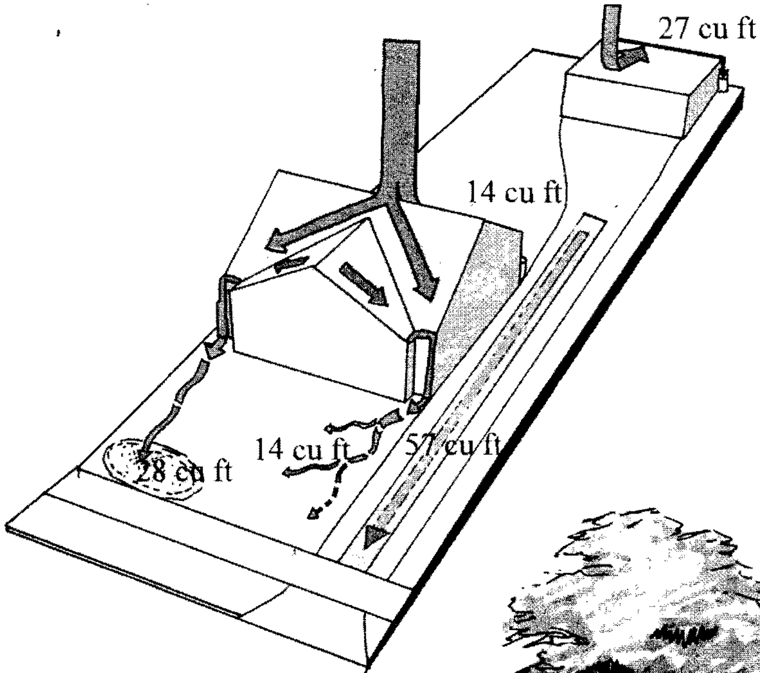

Figure 29.3 *Type 2 Proposed Hydrology*

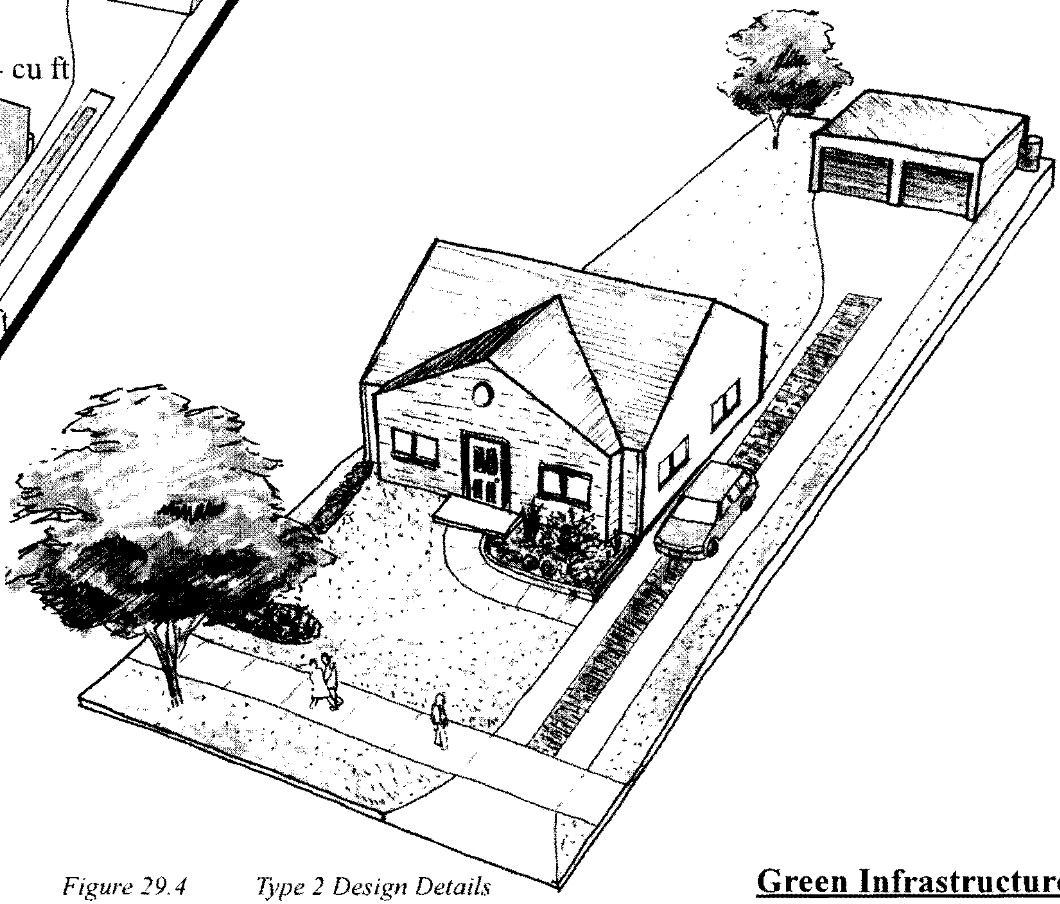

Figure 29.4 *Type 2 Design Details*

<u>Garage</u>

Rain Barrels 27 cu ft

<u>Residence</u>

Rain Barrels 14 cu ft

Lawn 14 cu ft

Rain Garden 28 cu ft

<u>Driveway</u>

Porous Pavement 57 cu ft

<u>100%</u> Storage Potential from a .75" rainfall event

<u>Green Infrastructure Application</u>

6 Rain Barrels

1 Rain Garden (35 sq ft)

1 Porous Pavement (140 sq ft)

XI . TYPE 3 RESIDENCE - EXISTING CONDITI(.S
Along 119th St.

With the largest from lawns, Type 3 homes will enjoy the lowest impact on their existing infrastructure. Direct disconnect of the downspouts to the front lawn allow the lawn to efficiently infiltrate the stormwater

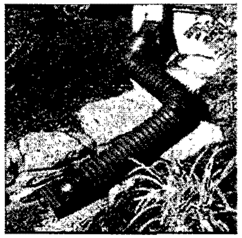

Figure 30.1 Downspout Disconnect
(Camarata, p. 43)

Porous Pavement

Driveways create a good majority of the total runoff from a residential site that likewise creates a direct connection to the public ROW.

A solution to the issue outside of adjustments to the landscape would be the installation of a porous strip along the driveway. Following the linear nature of the driveway, the strip will collect water as it migrates down the sloped impervious surface to the roadway.

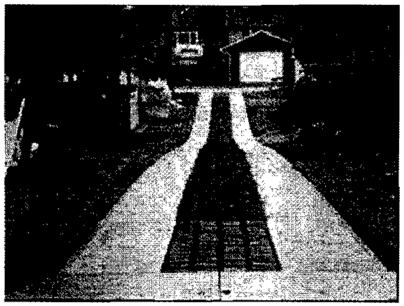

Figure 30.2 Porous Driveway Strip
(Camarata, p. 5)

Type 3 Residential Lot- 119th. St.			
	square feet	*cubic feet*	*gallons*
Garage	480	30	224
House	675	42.19	315
Driveway	800	50	374
Total	**1,955**	**122.19**	**913**

Table 30.1 Type 3 Impervious Surface Analysis

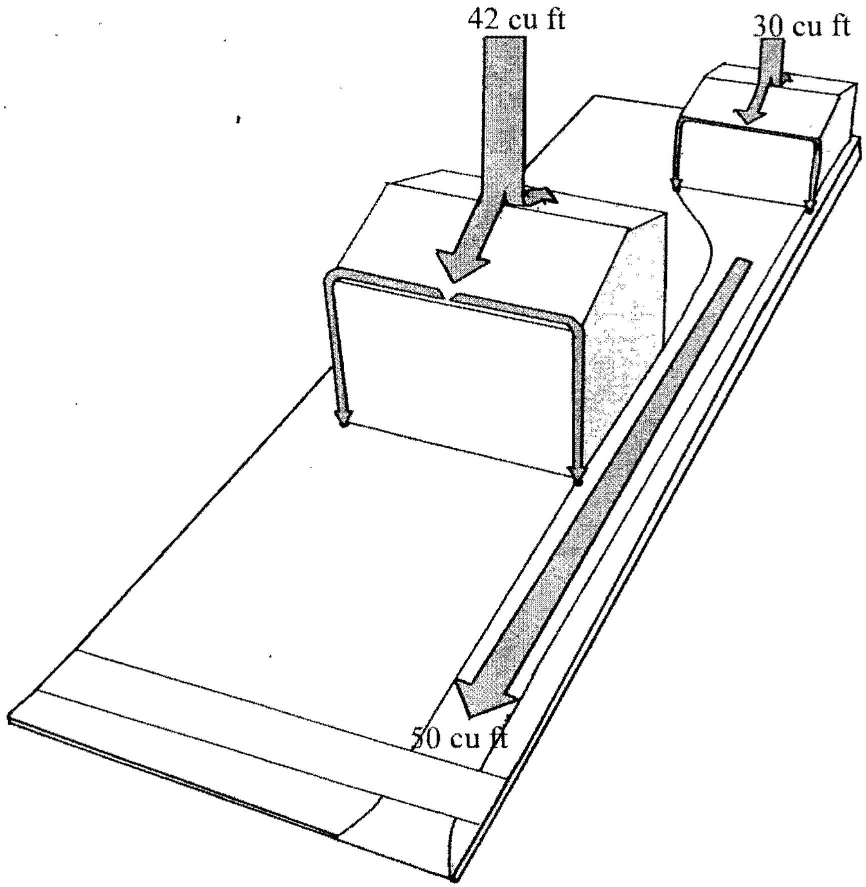

Figure 30.3 Type 3 Existing Runoff Hydrology

TYPE 3 RESIDENCE - PROPOSED GREE INFRASTRUCTURE APPLICATIONS

Rainfall Level *(in)*	Green Infrastructure Design	Application	Number	Storage Potential *(cu ft)*	Total Runoff Potential *(cu ft)*	Stormwater Storage *(cu ft)*	Percentage Reduction	Remaining Storage Potential *(cu ft)*
0.75	Garage	Rain Barrels	4	37.43	30.00	30.00	100%	7.43
0.75	Residence	Rain Barrels	2	16.71	10.55	10.55	100%	6.16
0.75		Lawn Infiltration	1	364.22	31.64	31.64	100%	332.58
0.75	Driveway	Porous Pavement	1	140.00	50.00	50.00	100%	90.00
		TOTAL		**558.36**	**122.19**	**122.19**	**100%**	**436.17**
1	Garage	Rain Barrels	4	37.43	40.00	37.43	94%	-2.57
1	Residence	Rain Barrels	2	16.71	14.06	14.06	100%	2.65
1		Lawn Infiltration	1	346.88	42.19	42.19	100%	304.69
1	Driveway	Porous Pavement	1	140.00	66.67	66.67	100%	73.33
		TOTAL		**541.02**	**162.92**	**160.35**	**98%**	**378.10**
2	Garage	Rain Barrels	4	37.43	80.00	37.43	47%	-42.57
2	Residence	Rain Barrels	2	16.71	28.13	16.71	59%	-11.41
2		Lawn Infiltration	1	277.50	84.38	84.38	100%	193.13
2	Driveway	Porous Pavement	1	140.00	133.33	133.33	100%	6.67
		TOTAL		**471.64**	**325.83**	**271.85**	**83%**	**145.81**

Table 30.2 Residential Lot Stormwater Generation & Storage for Varying Rainfall Levels

TYPE 3 RESIDENCE - DESIGN DETAILS
Along 119th St.

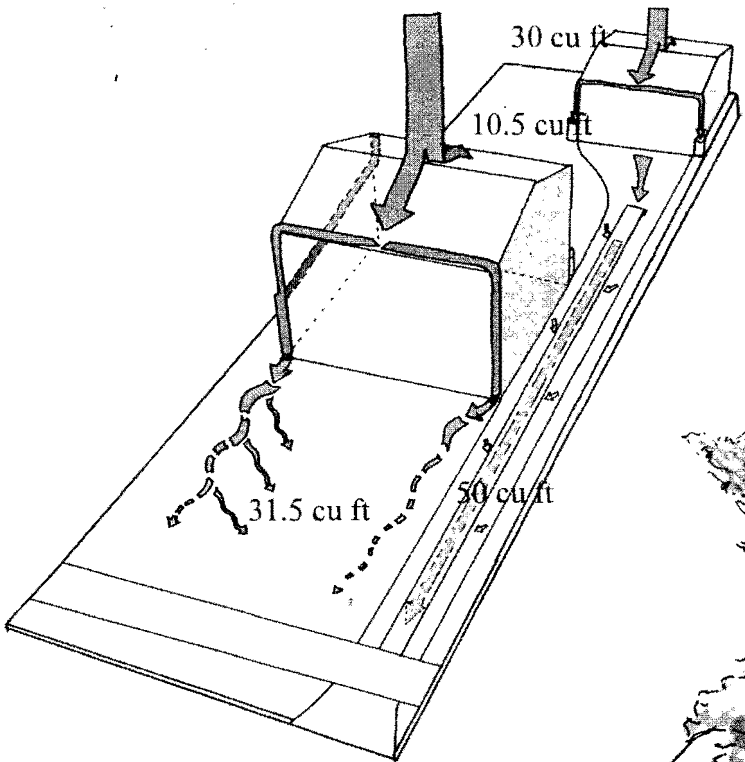

Figure 30.4 Type 3 Proposed Hydrology

Figure 30.5 Type 3 Design Details

<u>Garage</u>

Rain Barrels 30 cu ft

<u>Residence</u>

Rain Barrels 10.5 cu ft

Lawn 31.5 cu ft

<u>Driveway</u>

Porous Pavement 50 cu ft

<u>100%</u> Storage Potential from a .75" rainfall event

<u>Green Infrastructure Application</u>

6 Rain Barrels

1 Porous Pavement (140 sq ft)

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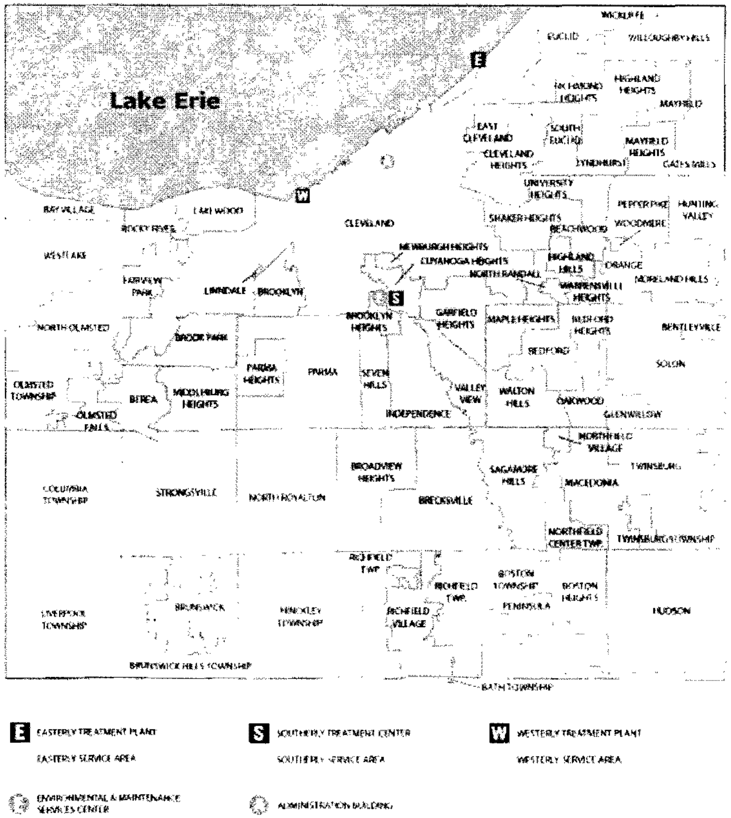
APPENDIX A NEORSD DATA



Cleveland NEORSD Treatment Regions

CSO Identification number	CSO Location - Description	Number of overflows per year (ESTIMATE)
211	NINE-MILE CREEK, EAST OF COIT RD., BETWEEN RR TRACKS	77
212	BELVOIR BLVD. OPPOSITE QUILLIAMS AVE.(EAST SIDE OF CREEK)	32
214	BEHIND AMERICAN STEEL SUPPLIES @ SARANAC RD. & E. 170TH ST. ALONG RR TRACKS	63
215	WEST SIDE OF DOAN BROOK @ ST. CLAIR AVENUE	0
216	WEST OF PARKGATE AVE. & EAST BLVD., EAST SIDE OF DOAN BROOK	0
217	WEST OF MARTIN LUTHER KING BLVD. & E. 98TH ST., EAST SIDE OF DOAN BROOK	53
242	E. 142ND ST. & LAKESHORE BLVD.	14
243	IN RAVINE, WEST OF WARNER RD., SOUTH OF GARFIELD RD.	33
245	EDGEPARK DR. @ E. 117TH ST. (NORTH)	51
246	BROADWAY AVE. @ MILL CREEK, EAST WALL OF BRIDGE	0
247	EAST BLVD. @ CRANWOOD CREEK, NORTH OF THORNHURST AVE.	1
249	450' EAST OF E. 119TH ST. & 250' NORTH OF MCCRACKEN RD.	6
250	ALONG CUYAHOGA RIVER, 370' SOUTH OF CANAL RD., EAST SIDE OF I-77 BRIDGE	13
251	ALONG B&O RR TRACKS, 2200' NORTH OF CANAL RD.	49

Cleveland CSO Frequency Chart

A ENDIX B SOIL DESCRIPTIONS

Available Water Capacity (AWC) - Refers to the quantity of water that the soil is capable of storing for use by plants. The capacity for water storage is given in centimeters of water per centimeter of soil for each soil layer. The capacity varies, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure, with corrections for salinity and rock fragments. Available water capacity is an important factor in the choice of plants or crops to be grown and in the design and management of irrigation systems. It is not an estimate of the quantity of water actually available to plants at any given time. Available water supply (AWS) is computed as AWC times the thickness of the soil. For example, if AWC is 0.15 cm/cm, the available water supply for 25 centimeters of soil would be 0.15 x 25, or 3.75 centimeters of water.

Saturated Hydraulic Conductivity (Ksat)- Refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields. For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used. The numeric Ksat values have been grouped according to standard Ksat class limits

Drainage Class- refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized-excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained.

Hydrologic Soil Group Rating- ased on estimates of runoff potential. Soils are assigned toone of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The soils in the United States are assigned to four groups (A, B, C, and D). The groups are defined as follows:

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.